REPORT

OF THE

FIFTY-SEVENTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

MANCHESTER IN AUGUST AND SEPTEMBER 1887.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1888.

Office of the Association: 22 ALBEMARLE STREET, LONDON, W.

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
LONDON

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OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive

gratuitously the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.

2. *At reduced or Members' Price*, viz., two-thirds of the Publication Price. —Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.[1]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organizing Sectional Committees.[2]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[3] and of preparing Reports

[1] Revised by the General Committee, 1884.

[2] Passed by the General Committee, Edinburgh, 1871.

[3] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting.* It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the

thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first meeting. The Sectional Presidents of former years are *ex officio* members of the Organizing Sectional Committees.[1]

An Organizing Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the General Committee, after which their functions as an Organizing Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2 No paper shall be read until it has been formally accepted by the

several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before.........................., addressed thus—'General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ....' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and Abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Secretary, *before the conclusion of the Meeting.*

[1] Added by the General Committee, Sheffield, 1879.

[2] Revised by the General Committee, Swansea, 1880.

[3] Passed by the General Committee, Edinburgh, 1871.

[4] The meeting on Saturday was made optional by the General Committee at Southport, 1883.

Committee of the Section, and entered on the minutes accord-

Rep. Brit. Assoc 1887 (88)
p 86.

Norman, A. M.

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Committee of the Section, and entered on the minutes accordingly.

3. Papers which have been reported on unfavourably by the Organizing Committees shall not be brought before the Sectional Committees.[1]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee.[2] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxxiii.), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

[1] These rules were adopted by the General Committee, Plymouth, 1877.

[2] This and the following sentence were added by the General Committee, 1871.

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such Report has been received.[1]

Notices regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next Meeting of the Association) forward to the General Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire *a week before* the opening of the ensuing Meeting; nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, Professor A. W. Williamson, University College, London, W.C., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

[1] Passed by the General Committee at Sheffield, 1879.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken,[1] and the reading of communications, in the order previously made public, commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

Corresponding Societies.[2]

(1.) Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

[1] The meeting on Saturday may begin, if desired by the Committee, at any time not earlier than 10 or later than 11. Passed by the General Committee at Southport, 1883.

[2] Passed by the General Committee, 1884.

(2.) Applications may be made by any Society to be placed on the List of Corresponding Societies. Application must be addressed to the Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

(3.) A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

(4.) Every Corresponding Society shall return each year, on or before the 1st of June, to the Secretary of the Association, a schedule, properly filled up, which will be issued by the Secretary of the Association, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

(5.) There shall be inserted in the Annual Report of the Association a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

(6.) A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

(7.) The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

(8.) The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

(9.) The Secretaries of each Section shall be instructed to transmit to the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

(10.) It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be

able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of [1]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers, General and Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting.
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

(3) There shall be not more than twenty-five Ordinary Members, of whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year—observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of the Members of General Committee whom they recommend for election as Members of Council.

Passed by the General Committee, Belfast, 1874.

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.

The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C E.	R. D. Darbishire, Esq., B.A., F.G S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq. M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.

WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S. L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk. His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol. Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S. L. & E., F.G.S. The Hon. the Lord Provost of Glasgow. Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S. L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S. L. & E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S. L. & E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe. The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin. The Provost of Trinity College, Dublin. His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S. L. & E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.

ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology. SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D. B.Sc
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., Ph.D., LL.D., F.R.S.L. & E., F.C.S. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S. L. & E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S. L. & E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.
SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., PH.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.
SECTION A.—MATHEMATICS AND PHYSICS.		
1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.

Date and Place	Presidents	Secretaries
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter......	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford...	Prof. H. J. S. Smith, F.R.S.	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol......	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Prof. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.,	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S	C. Carpmael, W. M. Hicks, Prof. A. Johnson, Prof. O. J. Lodge, Dr. D. MacAlister.
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

Date and Place	Presidents	Secretaries
1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope..........................	Mr. Johnston, Dr Christison.
	SECTION B.—CHEMISTRY AND MINERALOGY.	
1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol......	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.

Date and Place	Presidents	Secretaries
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, Dr. W. R. Eaton Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S., F.C.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.

Date and Place	Presidents	Secretaries
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G.B.Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G.B.Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham.—*Geography*, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool ..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.

[1] At a meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section,"' for Presidents and Secretaries of which see page lviii.

Date and Place	Presidents	Secretaries
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, LL.D., F.R.S., F.G.S.	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

Date and Place	Presidents	Secretaries
1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman.......................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lviii.]

1848. Swansea ...	L. W. Dillwyn, F.R.S..........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lviii.

Date and Place	Presidents	Secretaries
1860. Oxford	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.
	SECTION D (*continued*).—BIOLOGY.[1]	
1866. Nottingham	Prof. Huxley, LL.D., F.R.S. —*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.

[1] At a meeting of the General Committee in 1865, it was resolved:—'That the title of Section D be changed to Biology;' and 'That for the word "Subsection," in the rules for conducting the business of the Sections, the word "Department" be substituted.'

Date and Place	Presidents	Secretaries
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J.GwynJeffreys,LL.D.,F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A.,F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S. —*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S. —*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	Richard Owen, C.B., M.D., F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, LL.D., F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, M.D., F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S. —*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, M.A., F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, M.A., F.R.S.	G. W. Bloxam, W. Heape, J. B Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal[2]...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen ...	Prof. W. C. McIntosh, M.D., LL.D., F.R.S. L. & E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887 Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.

[1] By direction of the General Committee at Southampton (1882) the Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

[2] By authority of the General Committee, Anthropology was made a separate Section, for Presidents and Secretaries of which see p. lxiii.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

Date and Place	Presidents	Secretaries
1833. Cambridge	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S.	Dr. G. O. Rees, F. Ryland.
1840. Glasgow	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D.	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton.	Prof. Owen, M.D., F.R.S.	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1]	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S.L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D.	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. lii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A.	Prof. Buckley.
1848. Swansea	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lv.). The Section being then vacant was assigned in 1851 to Geography.

[2] *Vide* note on page lvi.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S..........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S..........	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, Clements R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S..........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. Oliphant Wood.

Date and Place	Presidents	Secretaries
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S.L.&E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol......	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork.........	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.

Date and Place	Presidents	Secretaries
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.........	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford......	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath.........	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich....	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter......	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol......	James Heywood, M.A., F.R.S., Pres.S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin......	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.

Date and Place	Presidents	Secretaries
1881. York	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, Prof. J. E. C. Munro, G. H. Sargant.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A.	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton.	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S.	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.

Date and Place	Presidents	Secretaries
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	Wm. Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S..........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	James Abernethy, V.P. Inst. C.E., F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport	James Brunlees, F.R.S.E., Pres.Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.

ANTHROPOLOGICAL SCIENCE.

SECTION H.—ANTHROPOLOGY.

1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.

Date and Place	Presidents	Secretaries
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.

LIST OF EVENING LECTURES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson.....................	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.

Date and Place	Lecturer	Subject of Discourse
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G.B. Airy, F.R.S., Astron. Royal	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S.	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S. ...	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S.	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S....	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.	Some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilization.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.

Date and Place	Lecturer	Subject of Discourse
1874. Belfast	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarized Light.
	F. J. Bramwell, F.R.S.	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth ...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.	The new Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S.	Mental Imagery.
1881. York	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S.	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick, F.R.S.E.	Galvani and Animal Electricity.
1884. Montreal ...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen ...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E.	The Great Ocean Basins.
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton, K.C.M.G.	Explorations in Central Africa.

LECTURES TO THE OPERATIVE CLASSES.

1867. Dundee	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool ...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S.	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.

Date and Place	Lecturer	Subject of Discourse
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877. Plymouth...	W. H. Preece....................	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York.........	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snow-flakes.
1882. Southampton.	John Evans, D.C.L. Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S..........	Comets.
1885. Aberdeen ...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE MANCHESTER MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Professor Sir R. S. Ball, M.A., LL.D., F.R.S., F.R.A.S., M.R.I.A., Astronomer Royal for Ireland.

Vice-Presidents.—Professor J. C. Adams, F.R.S.; Dr. John Hopkinson, F.R.S.; Professor the Rev. Bartholomew Price, V.P.R.S.; Professor Lord Rayleigh, Sec.R.S.; Professor H. A. Rowland; Professor Schuster, F.R.S.; Professor Balfour Stewart, F.R.S.; Professor Sir W. Thomson, F.R.S.

Secretaries.—Robert E. Baynes, M.A. (*Recorder*); R. T. Glazebrook, F.R.S.; Professor H. Lamb, F.R.S.; W. N. Shaw, M.A.

SECTION B.—CHEMICAL SCIENCE.

President.—Edward Schunck, Ph.D., F.R.S., F.C.S.

Vice-Presidents.—Professor C. Schorlemmer, F.R.S.; Professor T. E. Thorpe, F.R.S.; Sir F. A. Abel, C.B., F.R.S.; W. Crookes, F.R.S.; Professor Dewar, F.R.S.; Professor H. B. Dixon, F.R.S.; Dr. W. J. Russell, F.R.S.; Professor A. W. Williamson, F.R.S.

Secretaries.—Professor P. Phillips Bedson, D.Sc. (*Recorder*); H. Forster Morley, D.Sc.; W. Thomson.

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President.—Henry Woodward, LL.D., F.R.S., F.G.S.

Vice-Presidents. — Professor Bonney, F.R.S.; Professor Comm. G. Capellini, Sc.D.; Professor W. Boyd Dawkins, F.R.S.; Dr. T. Sterry Hunt, F.R.S.; Professor J. W. Judd, F.R.S.; Professor T. Rupert Jones, F.R.S.; Professor Otto Torell, Ph.D.; Professor F. Zirkel, Ph.D.

Secretaries.—J. E. Marr, M.A.; J. J. H. Teall, M.A.; W. Topley, F.G.S. (*Recorder*); W. W. Watts, M.A.

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President.—Professor Alfred Newton, M.A., F.R.S., F.L.S., V.P.Z.S.

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Secretaries.—C. Bailey, F.L.S.; F. E. Beddard, M.A.; S. F. Harmer, M.A.; Walter Heape, M.A. (*Recorder*); W. L. Sclater, B.A.; Professor H. Marshall Ward, M.A.

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President.—Colonel Sir Charles Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.

Vice-Presidents.—H. W. Bates, F.R.S.; Dr. John Rae, F.R.S.; Henry Lee; Admiral Sir Erasmus Ommanney, C.B., F.R.S.; General Sir H. E. L. Thuillier, C.S.I., F.R.S.; General J. T. Walker, C.B., F.R.S.; Colonel Sir C. W. Wilson, K.C.B., F.R.S.

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Secretaries.—Rev. W. Cunningham, D.Sc. (*Recorder*); F. Y. Edgeworth, M.A.; T. H. Elliott, F.S.S.; C. Hughes, B.A.; Professor J. E. C. Munro, LL.D.; G. H. Sargant.

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President.—Professor Osborne Reynolds, M.A., LL.D., F.R.S.

Vice-Presidents.—Sir F. J. Bramwell, F.R.S.; E. H. Carbutt, Pres. Inst.M.E.; T. Hawksley, F.R.S.; Jeremiah Head, M.Inst.C.E.; W. H. Preece, F.R.S.; J. Robinson, M.Inst.C.E.

Secretaries.—C. F. Budenberg, B.Sc.; W. Bayley Marshall; Edward Rigg, M.A. (*Recorder*).

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President.—Professor A. H. Sayce, M.A.

Vice-Presidents.—John Evans, Treas.R.S.; H. H. Howorth, M.P.; Professor H. N. Moseley, F.R.S.; William Pengelly, F.R.S.; General Pitt-Rivers, F.R.S.; Dr. E. B. Tylor, F.R.S.

Secretaries.—G. W. Bloxam, M.A. (*Recorder*); J. G. Garson, M.D.; A. M. Paterson, M.D.

THE BRITISH ASSOCIATION FOR

Dr. THE GENERAL TREASURER'S ACCOUNT

1886-87. RECEIPTS.

	£	s.	d.
By Balance of account rendered at Birmingham Meeting	1869	5	5
„ Receipt of Life Compositions to date ...	320	0	0
„ Receipt of Annual Subscriptions to date ...	648	0	0
„ New Annual Memberships ...	356	0	0
„ Associates' Tickets at Birmingham Meeting ...	1067	0	0
„ Ladies' Tickets at Birmingham Meeting ...	429	0	0
„ Sale of Publications ...	49	15	2
„ Interest on Exchequer Bills ...	43	10	0
„ Dividends on Consols ...	247	0	8
„ Amount of Rent received from London Mathematical Society, year ending September 29, 1886 ...	12	15	0
„ Unexpended balance of grant made to the Chepstow Observatory Committee ...	25	0	0
„ Unexpended balance of grant made for investigation of Lymphatic System ...	14	0	0
	£5081	6	3

THE ADVANCEMENT OF SCIENCE.

(not including receipts at the Manchester Meeting). *Cr.*

1886–87. PAYMENTS.

	£	s.	d.
To Messrs. Spottiswoode & Co. for printing, &c. (1885–86)	1286	11	6
„ Payment of Salaries (1886–87)	545	0	0
„ Rent of Office, &c., in Albemarle Street (1886–87)	117	0	0
„ Expenses of Birmingham Meeting, including Printing and Advertising, also incidental and petty cash expenses, &c.	227	6	8

GRANTS.

	£	s.	d.
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Standards of Light (1886 grant)	20	0	0
Silent Discharge of Electricity	20	0	0
Exploration of Cae Gwyn Cave, North Wales	20	0	0
Investigation of Lymphatic System	25	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Plymouth Biological Station	50	0	0
Naples Biological Station	100	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Regulation of Wages	10	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Ben Nevis Observatory	75	0	0
Prehistoric Race of Greek Islands	20	0	0
Flora and Fauna of the Cameroons	75	0	0
Provincial Museum Reports	5	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Coal Plants of Halifax	25	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Magnetic Observations	26	2	0
'Manure' Gravels of Wexford	10	0	0
Electrolysis	30	0	0
Fossil Phyllopoda	20	0	0
Racial Photographs, Egyptian	20	0	0
Standards of Light (1887 grant)	10	0	0
Migration of Birds	30	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Electrical Standards	50	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Absorption Spectra	40	0	0
Solar Radiation	18	10	0
Circulation of Underground Waters	5	0	0
Erratic Blocks	10	0	0
	1186	18	0

	£	s.	d.	£	s.	d.
By Balance at Bank of England, Western Branch	1636	4	10			
„ Deposit in Manchester and Salford Bank, Manchester	82	5	3			
				1718	10	1
Plus Consols, £8,500; Exchequer Bills, £2,000.						
				£5081	6	3

ALEX. W. WILLIAMSON.

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.......	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham.........	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton......	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.......	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham.........	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2 ...	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds..................	Richard Owen, M.D., D.C.L....	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ...	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham.........	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20 ...	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25 ...	Swansea	A. C. Ramsay, LL.D., F.R.S....	144	11
1881, Aug. 31 ...	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23 ...	Southampton	Dr. C. W. Siemens, F.R.S.......	178	17
1883, Sept. 19 ...	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27 ...	Montreal	Prof. Lord Rayleigh, F.R.S. ...	235	20
1885, Sept. 9 ...	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1 ...	Birmingham.........	Sir J.W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31 ...	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86

* Ladies were not admitted by purchased Tickets until 1843. † Tickets of Admission to Sections on

Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total			
...	...	...	...	...	353	....	....	1831
...	...	...	...	...	...	....	....	1832
...	...	...	...	...	900	....	....	1833
...	...	...	...	...	1298	....	£20 0 0	1834
...	...	...	...	...	...	....	167 0 0	1835
...	...	...	...	...	1350	....	435 0 0	1836
...	...	...	...	...	1840	....	922 12 6	1837
...	...	...	1100*	...	2400	....	932 2 2	1838
...	...	...	...	34	1438	....	1595 11 0	1839
...	...	...	...	40	1353	....	1546 16 4	1840
46	317	...	60*	...	891	....	1235 10 11	1841
75	376	33†	331*	28	1315	....	1449 17 8	1842
71	185	...	160	...	...	....	1565 10 2	1843
45	190	9†	260	...	...	....	981 12 8	1844
94	22	407	172	35	1079	....	831 9 9	1845
65	39	270	196	36	857	....	685 16 0	1846
197	40	495	203	53	1320	....	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 3 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1538 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	29	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887

ncluding Ladies. § Fellows of the American Association were admitted as Honorary Members for this Meeting.

OFFICERS AND COUNCIL, 1887–88.

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The Right Worshipful the MAYOR OF MANCHESTER.
The Right Worshipful the MAYOR OF SALFORD.
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The PRINCIPAL of the Owens College, Manchester.
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SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.INST.C.E.

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The Right Hon. and Right Rev. the LORD BISHOP OF BATH AND WELLS, D.D.
The Right Rev. the BISHOP OF CLIFTON.
The Right Worshipful the MAYOR OF BATH.
The Right Worshipful the MAYOR OF BRISTOL.
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The Venerable the ARCHDEACON OF BATH. (Nominated by the Council.)
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LOCAL TREASURER FOR THE MEETING AT BATH.

JOHN STONE, Esq.

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A. G. VERNON HARCOURT, Esq., M.A., LL.D., F.R.S., F.C.S., Cowley Grange, Oxford.

SECRETARY.

ARTHUR T. ATCHISON, Esq., M.A., 22 Albemarle Street, London, W.

GENERAL TREASURER.

Professor A. W. WILLIAMSON, Ph.D., LL.D., F.R.S., F.C.S., University College, London, W.C.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

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The Right Hon. Lord RAYLEIGH, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S.
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The Duke of Argyll, K.G., K.T.
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George Griffith, Esq., M.A., F.C.S.
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Dr. W. H. Perkin, F.R.S. | W. H. Preece, Esq., F.R.S. | Prof. W. G. Adams, F.R.S.

REPORT OF THE COUNCIL.

Report of the Council for the year 1886–87, *presented to the General Committee at Manchester, on Wednesday, August* 31, 1887.

The Council have received reports during the past year from the General Treasurer, and his account for the year will be laid before the General Committee this day.

Since the Meeting at Birmingham the following have been elected Corresponding Members of the Association:—

Dr. Finsch.
Dr. O. W. Huntington.
Dr. A. König.
Lieut. R. Kund.
Professor Leeds.
Professor H. Carvill Lewis.
Professor John Trowbridge.

The Council have nominated Mr. Oliver Heywood a Vice-President of the meeting at Manchester.

An invitation for the year 1889 will be presented from Newcastle-upon-Tyne; but the invitations from Melbourne and Sydney have been withdrawn.

The following resolutions were referred by the General Committee to the Council for consideration, and action if desirable:—

(*a*) 'That the Council be requested to consider the question of rendering the Reports and other papers communicated to the Association more readily accessible to the members and others by issuing a limited number of them in separate form, or in associated parts, in advance of the annual volume.'

The Council, after careful consideration of the question, are of opinion that a certain number of copies of the more important Reports presented to the Sections of the Association should be kept in stock and sold separately, the number of copies printed and the price of each Report to be fixed by the Secretaries after communication with the officers of the several Sections.

(*b*) 'That the Council be requested to consider the advisability of selling publicly the Presidential Addresses.'

The Council have considered the question, and are of opinion that it is desirable that printed copies of the addresses of the President and the Presidents of Sections should be stitched together and sold.

That a number of copies not exceeding 1,000 should be printed, and that these should be placed on sale, at the price of one shilling, through agents or otherwise, as may be considered most suitable.

(*c*) 'That the Council be requested to consider the advisability of calling the attention of the proprietor of Stonehenge to the danger in which several of the stones are at the present time from the burrowing of rabbits, and also to the desirability of removing the wooden props which support the horizontal stone of one of the trilithons; and in view of the great value of Stonehenge as an ancient national monument to express the hope of the Association that some steps will be taken to remedy these sources of danger to the stones.'

The Council have carefully considered the question, and having had the advantage of perusing the detailed report recently prepared by a deputation of the Wilts Archæological and Natural History Society on the condition of the whole of the stones constituting Stonehenge, are of opinion that the proprietor should be approached with the expression of

a hope that he will direct such steps to be taken as shall effectually prevent further damage.

(*d*) 'That the Council be requested to consider whether a memorial should be presented to Her Majesty's Government, urging them to undertake and supervise Agricultural Experiments, and to procure further and more complete Agricultural Statistics.'

The Council have considered the question, and are not prepared to memorialise the Government on the subject.

The question of the re-arrangement of the journal has been brought before the Council by Mr. J. B. Martin, and after careful consideration the Council are of opinion that it is unnecessary to print in each number of the Journal the list of the papers read on the previous day; also that it would be well to place the list of officers of each Section at the head of the list of papers to be read in that Section. The Council wish to obtain the sanction of the General Committee to these alterations.

The Council, having considered a letter addressed to them by Mr. R. H. Scott, are of opinion that it should be an instruction to the secretaries of all committees, other than committees of Sections, to send notices of all meetings to each member of a committee, and that the draft report of the committee should first be sent in proof to each member, and then submitted to a meeting of the committee specially called for the purpose.

The Corresponding Societies Committee, consisting of Mr. Francis Galton (Chairman), Professor A. W. Williamson, Sir Douglas Galton, Professor Boyd Dawkins, Sir Rawson Rawson, Dr. J. G. Garson, Dr. J. Evans, Mr. J. Hopkinson, Professor R. Meldola (Secretary), Mr. W. Whitaker, Mr. G. J. Symons, and General Pitt-Rivers, having by an oversight not been reappointed at Birmingham last year, the Council have requested these gentlemen to continue the work of their Committee, and now nominate them for re-election, with the addition of the names of Mr. W. Topley, Mr. H. G. Fordham, and Mr. William White. The report of the Corresponding Societies Committee is herewith submitted to the General Committee.

In accordance with the regulations the five retiring Members of the Council will be:—

Mr. W. Pengelly.
Sir R. Temple.
Dr. De La Rue.
Sir F. J. Bramwell.
Mr. J. C. Hawkshaw.

The Council recommend the re-election of the other ordinary Members of Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

Abney, Capt. W. de W., F.R.S.
Ball, Sir R. S., F.R.S.
Barlow, W. H., Esq., C.E., F.R.S.
Blanford, W. T., Esq., F.R.S.
Crookes, W., Esq., F.R.S.
Darwin, Prof. G. H., F.R.S.
Dawkins, Prof. W. Boyd, F.R.S.
Dewar, Prof. J., F.R.S.
*Douglass, Sir James, F.R.S.
Flower, Prof. W. H., C.B., F.R.S.
Gladstone, Dr. J. H., F.R.S.
Godwin-Austen, Lieut.-Col. H. H., F.R.S.
Henrici, Prof. O., F.R.S.
Judd, Prof. J. W., F.R.S.
Martin, J. B., Esq., F.S.S.
M'Leod, Prof. H., F.R.S.
Moseley, Prof. H. N., F.R.S.
Ommanney, Admiral Sir E., C.B., F.R.S.
Roberts-Austen, Prof. W. C., F.R.S.
*Schuster, Prof., F.R.S.
*Sidgwick, Prof. H.
*Schäfer, Prof., F.R.S.
Thiselton-Dyer, W. T., Esq., C.M.G., F.R.S.
Thorpe, Prof. T. E., F.R.S.
*Woodward, Dr. H., F.R.S.

Recommendations adopted by the General Committee at the Manchester Meeting in August and September 1887.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That Sir R. S. Ball, Dr. G. Johnstone Stoney, Professors Everett, Fitzgerald, Hicks, Carey Foster, O. J. Lodge, Ewing, Poynting, Macgregor, Genese, W. G. Adams, and Lamb, Messrs. Baynes, A. Lodge, Fleming, W. N. Shaw, Glazebrook, Hayward, Lant Carpenter, Culverwell, and Greenhill, Dr. Muir, and Messrs. G. Griffith and J. Larmor be a Committee for the purpose of considering the desirability of introducing a Uniform Nomenclature for the Fundamental Units of Mechanics, of co-operating with other bodies engaged in similar work, and of reporting to the next meeting of the Association; that Mr. E. P. Culverwell be the Secretary, and that the sum of 10*l*. be placed at their disposal for the purpose.

That General J. T. Walker, Sir William Thomson, Sir J. H. Lefroy, General R. Strachey, Professors A. S. Herschel, G. Chrystal, C. Niven, J. H. Poynting, A. Schuster, and Mr. C. V. Boys be a Committee for the purpose of inviting designs for a good Differential Gravity Meter in supersession of the pendulum, whereby satisfactory results may be obtained at each station of observation in a few hours instead of the many days over which it is necessary to extend pendulum observations; that Professor Poynting be the Secretary, and that the sum of 10*l*. be placed at their disposal for the purpose.

That Professor Crum Brown, Mr. Milne-Home, Mr. John Murray, Mr. Buchan, and Lord McLaren be reappointed a Committee for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations on Ben Nevis; that Professor Crum Brown be the Secretary, and that the sum of 150*l*. be placed at their disposal for the purpose.

That Professor G. Carey Foster, Sir William Thomson, Professor Ayrton, Professor J. Perry, Professor W. G. Adams, Lord Rayleigh, Dr. O. J. Lodge, Dr. John Hopkinson, Dr. A. Muirhead, Mr. W. H. Preece, Mr. Herbert Taylor, Professor Everett, Professor Schuster, Dr. J. A. Fleming, Professor G. F. Fitzgerald, Mr. R. T. Glazebrook, Professor Chrystal, Mr. H. Tomlinson, Professor W. Garnett, Professor J. J. Thomson, Mr. W. N. Shaw, Mr. J. T. Bottomley, and Mr. Thomas Gray be reappointed a Committee for the purpose of making experiments for improving the construction of practical Standards for use in Electrical Measurements; that Mr. Glazebrook be the Secretary, and that the sum of 80*l*. be placed at their disposal for the purpose.

That Professors Balfour Stewart and Sir W. Thomson, Sir J. H. Lefroy, Professors G. H. Darwin, G. Chrystal, and S. J. Perry, Mr. C. H.

Carpmael, Professor Schuster, Mr. G. M. Whipple, Captain Creak, the Astronomer Royal, Mr. William Ellis, Professor W. G. Adams, and Mr. W. Lant Carpenter be reappointed a Committee for the purpose of considering the best means of comparing and reducing Magnetic Observations; that Professor Balfour Stewart be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Professor G. Forbes, Captain Abney, Dr. J. Hopkinson, Professor W. G. Adams, Professor G. C. Foster, Lord Rayleigh, Mr. Preece, Professor Schuster, Professor Dewar, Mr. A. Vernon Harcourt, Mr. H. Trueman Wood, Sir James Douglass, and Professor H. B. Dixon be reappointed a Committee for the purpose of reporting on Standards of Light; that Professor G. Forbes be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That the Committee consisting of Professors Armstrong and Lodge, Sir William Thomson, Lord Rayleigh, Fitzgerald, J. J. Thomson, Schuster, Poynting, Crum Brown, Ramsay, Frankland, Tilden, Hartley, S. P. Thompson, McLeod, Roberts-Austen, Rücker, Reinold, Carey Foster, and H. B. Dixon, Captain Abney, Drs. Gladstone, Hopkinson, and Fleming, and Messrs. Crookes, Shelford Bidwell, W. N. Shaw, J. Larmor, J. T. Bottomley, R. T. Glazebrook, J. Brown, E. J. Love, and John M. Thomson be reappointed a Committee for the purpose of considering the subject of Electrolysis in its Physical and Chemical bearings; that Professor Armstrong be the Chemical Secretary and Professor Lodge the Physical Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose, of which not more than 20*l.* is to be spent in printing and postage.

That Professors Balfour Stewart, Schuster, and Stokes, Mr. G. Johnstone Stoney, Sir H. E. Roscoe, Captain Abney, and Mr. G. J. Symons be reappointed a Committee for the purpose of considering the best methods of recording the direct intensity of Solar Radiation; that Professor Balfour Stewart be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professors Armstrong, Meldola, and Smithells, Drs. Gladstone, Russell, and Vernon Harcourt, Messrs. J. T. Dunn, Francis Jones, M. M. Pattison Muir, and W. A. Shenstone, and Professor Dunstan be a Committee for the purpose of inquiring into and reporting on the present methods adopted for teaching chemistry; that Professor Dunstan be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professors W. A. Tilden and H. E. Armstrong be reappointed a Committee for the purpose of investigating Isomeric Naphthalene Derivatives; that Professor H. E. Armstrong be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Dr. Russell, Captain Abney, Professor Hartley, and Dr. A. Richardson be a Committee for the purpose of investigating the action of light on the Hydracids of the Halogens in Presence of Oxygen; that Dr. A Richardson be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Professors McLeod and Ramsay, Mr. J. T. Cundall, and Mr. W. A. Shenstone be reappointed a Committee for the further investigation of the Influence of the Silent Discharge of Electricity on Oxygen and other gases; that Mr. W. A. Shenstone be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professors Tilden and W. Ramsay and Dr. W. W. J. Nicol be reappointed a Committee for the purpose of investigating the Properties of Solutions; that Dr. W. W. J. Nicol be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Professors Dewar, Odling, and Frankland, Mr. Crookes, and Professor P. F. Frankland be a Committee for the purpose of conferring with a Committee of the American Association with a view of forming a Uniform System of Recording the Results of Water Analysis; that Professor P. F. Frankland be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professors Tilden and W. Chandler Roberts-Austen, and Mr. T. Turner be reappointed a Committee for the purpose of investigating the Influence of Silicon on the Properties of Steel; that Mr. T. Turner be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Messrs. H. Bauerman, F. W. Rudler, J. J. H. Teall, and H. J. Johnston-Lavis be reappointed a Committee for the purpose of investigating the Volcanic Phenomena of Vesuvius and its neighbourhood; that Dr. H. J. Johnston-Lavis be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Professor W. C. Williamson and Mr. W. Cash be reappointed a Committee for the purpose of investigating the Flora of the Carboniferous Rocks of Lancashire and West Yorkshire; that Mr. Cash be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Mr. J. W. Davis, Mr. W. Cash, Dr. H. Hicks, Mr. G. W. Lamplugh, Mr. Clement Reid, Dr. H. Woodward, and Mr. T. Boynton be a Committee for the purpose of investigating an Ancient Sea-beach near Bridlington; that Mr. G. W. Lamplugh be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Dr. J. Evans, Professor W. J. Sollas, Dr. G. J. Hinde, and Messrs. W. Carruthers, R. B. Newton, J. J. H. Teall, F. W. Rudler, W. Topley, W. Whitaker, and E. Wethered be reappointed a Committee for the purpose of carrying on the Geological Record; that Mr. W. Topley be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Mr. R. Etheridge, Dr. H. Woodward, and Mr. A. Bell be reappointed a Committee for the purpose of reporting upon the 'Manure' Gravels of Wexford; that Mr. A. Bell be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Messrs. R. B. Grantham, C. E. De Rance, J. B. Redman, W. Topley, W. Whitaker, and J. W. Woodall, Major-General Sir A. Clarke, Admiral Sir E. Ommanney, Sir J. N. Douglass, Captain Sir George Nares, Captain J. Parsons, Captain W. J. L. Wharton, Professor J. Prestwich, and Messrs. E. Easton, J. S. Valentine, and L. F. Vernon Harcourt be reappointed a Committee for the purpose of inquiring into the Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other material in that Action; that Messrs. De Rance and Topley be the Secretaries, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Professors J. Prestwich, W. Boyd Dawkins, T. McK. Hughes, and T. G. Bonney, Dr. H. W. Crosskey, and Messrs. C. E. De Rance, H. G. Fordham, D. Mackintosh, W. Pengelly, J. Plant, and R. H.

Tiddeman be reappointed a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation; that Dr. Crosskey be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor E. Hull, Dr. H. W. Crosskey, Captain Sir Douglas Galton, Professor J. Prestwich, and Messrs. James Glaisher, E. B. Marten, G. H. Morton, James Parker, W. Pengelly, James Plant, I. Roberts, Fox Strangways, T. S. Stooke, G. J. Symons, W. Topley, Tylden-Wright, E. Wethered, W. Whitaker, and C. E. De Rance be reappointed a Committee for the purpose of investigating the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to various towns and districts from these formations; that Mr. De Rance be the Secretary, and that the sum of 5*l.* be placed at their disposal for the purpose.

That Dr. H. Woodward, Professor T. R. Jones, Mr. W. Pengelly, Professor W. Boyd Dawkins, Mr. R. Etheridge, and Professor Wiltshire be a Committee for the purpose of assisting the Palæontographical Society in the publication of Monographs of British Fossils; that Professor Wiltshire be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Mr. R. Etheridge, Mr. T. Gray, and Professor John Milne be reappointed a Committee for the purpose of investigating the Volcanic Phenomena of Japan; that Professor J. Milne be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Mr. R. Etheridge, Mr. W. H. Hudleston, Professor J. W. Judd, and Mr. R. G. Bell be a Committee for the purpose of preparing a Monograph upon the Molluscan Fauna of the Pliocene Beds of St. Erth; that Mr. R. G. Bell be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professors Schäfer, M. Foster, and Lankester and Dr. W. D. Halliburton be reappointed a Committee for the purpose of investigating the Physiology of the Lymphatic System; that Professor Schäfer be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Professors McKendrick, Struthers, Young, McIntosh, A. Nicholson, and Cossar Ewart and Mr. John Murray be reappointed a Committee for the purpose of aiding in the Biological Researches carried on at the Marine Biological Station at Granton, Scotland; that Mr. John Murray be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professor Foster, Professor Bayley Balfour, Mr. Thiselton-Dyer, Dr. Trimen, Professor Marshall Ward, Mr. Carruthers, and Professor Hartog be a Committee for the purpose of taking steps for the establishment of a Botanical Station at Peradeniya, Ceylon; that Professor Bower be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professor Lankester, Professor Milnes Marshall, Mr. Sedgwick, and Mr. G. H. Fowler be a Committee for the purpose of investigating the Development of the Oviduct and connected structures in certain freshwater Teleostei; that Mr. G. H. Fowler be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Professors McIntosh, Allman, Lankester, Burdon Sanderson, Cleland, Ewart, Stirling, McKendrick, Dr. Cleghorn and Dr. Traquair, be a Committee for the purpose of carrying on researches on the development of Fishes at the St. Andrews Marine Laboratory; that Professor McIntosh be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professors Newton and Flower, Mr. Carruthers, Mr. Sclater, and Mr. Thiselton-Dyer be a Committee for the purpose of reporting on the present State of our Knowledge of the Zoology and Botany of the West India Islands, and taking steps to investigate ascertained deficiencies in the Fauna and Flora; that Mr. Thiselton-Dyer be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Messrs. W. Carruthers, W. F. R. Weldon, J. G. Baker, G. M. Murray, and W. T. Thiselton-Dyer be a Committee for the purpose of exploring the Flora of the Bahamas; that Mr. W. T. Thiselton-Dyer be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Professor E. Ray Lankester, Mr. P. L. Sclater, Professor M. Foster, Mr. A. Sedgwick, Mr. Walter Heape, Professor A. C. Haddon, Professor Moseley, and Mr. Percy Sladen be reappointed a Committee for the purpose of making arrangements for assisting the Marine Biological Association Laboratory at Plymouth; that Mr. Percy Sladen be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Mr. John Cordeaux, Professor A. Newton, Mr. J. A. Harvie-Brown, Mr. W. E. Clarke, Mr. R. M. Barrington, and Mr. A. G. More be reappointed a Committee for the purpose of obtaining (with the consent of the Master and Elder Brethren of the Trinity House and the Commissioners of Northern and Irish Lights) Observations on Migration of Birds at Lighthouses and Lightvessels, and of reporting on the same; that Mr. Cordeaux be the Secretary, and that the sum of 30*l.* be placed at their disposal for the purpose.

That Mr. Thiselton-Dyer, Mr. Carruthers, Mr. Ball, Professor Oliver, and Mr. Forbes be reappointed a Committee for the purpose of continuing the preparation of a report on our present knowledge of the Flora of China; that Mr. Thiselton-Dyer be the Secretary, and that the sum of 75*l.* be placed at their disposal for the purpose.

That Professor Ray Lankester, Mr. P. L. Sclater, Professor M. Foster, Mr. A. Sedgwick, Professor A. M. Marshall, Professor A. C. Haddon, Professor Moseley, and Mr. Percy Sladen be reappointed a Committee for the purpose of arranging for the Occupation of a Table at the Zoological Station at Naples; that Mr. Percy Sladen be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That General J. T. Walker, General Sir J. H. Lefroy, Professor Sir William Thomson, Mr. Alexander Buchan, Mr. J. Y. Buchanan, Mr. John Murray, Dr. J. Rae, Mr. H. W. Bates, Captain W. J. Dawson, Dr. A. Selwyn, and Professor C. Carpmael be reappointed a Committee for the purpose of reporting upon the Depth of the permanently Frozen Soil in the Polar Regions, its geographical limits, and relation to the present poles of greatest cold; that Sir Henry Lefroy be the Reporter and Mr. H. W. Bates the Secretary, and that the sum of 5*l.* be placed at their disposal for the purpose.

That Mr. S. Bourne, Mr. F. Y. Edgeworth (Secretary), Professor H. S. Foxwell, Mr. Robert Giffen, Professor Alfred Marshall, Mr. J. B.

Martin, Professor J. S. Nicholson, Mr. R. H. Inglis Palgrave, and Professor H. Sidgwick be a Committee for the purpose of inquiring and reporting as to the Statistical Data available for determining the amount of the precious metals in use as money in the principal countries of the world, the chief forms in which the money is employed, and the amount annually used in the arts; that Mr. F. Y. Edgeworth be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Mr. S. Bourne, Mr. F. Y. Edgeworth (Secretary), Professor H. S. Foxwell, Mr. Robert Giffen, Professor Alfred Marshall, Mr. J. B. Martin, Professor J. S. Nicholson, Mr. R. H. Inglis Palgrave, and Professor H. Sidgwick be reappointed a Committee for the purpose of continuing to investigate the best method of ascertaining and measuring variations in the Value of the Monetary Standard; that Mr. F. Y. Edgeworth be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor Osborne Reynolds, Sir F. J. Bramwell, Sir James Douglass, Professor J. Thomson, Professor W. C. Unwin, and Messrs. W. Topley, J. Abernethy, E. Leader Williams, W. Shelford, J. A. Froude, J. N. Shoolbred, G. F. Deacon, G. F. Lister, A. R. Hunt, and W. H. Wheeler be a Committee for the purpose of investigating the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models; that Professor Osborne Reynolds be the Secretary, and that the sum of 200*l.* be placed at their disposal for the purpose.

That Sir Rawson Rawson, General Pitt-Rivers, Mr. Francis Galton, Dr. Muirhead, Mr. C. Roberts, Dr. J. Beddoe, Mr. H. H. Howorth, Mr. F. W. Rudler, Mr. G. W. Hambleton, Mr. Horace Darwin, Mr. G. W. Bloxam, Dr. Garson, and Dr. A. M. Paterson be a Committee for the purpose of investigating the effects of different occupations and employments on the Physical Development of the Human Body; that Mr. Bloxam be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Dr. E. B. Tylor, Dr. G. M. Dawson, General Sir J. H. Lefroy, Dr. Daniel Wilson, Mr. R. G. Haliburton, and Mr. George W. Bloxam be reappointed a Committee for the purpose of investigating and publishing reports on the physical characters, languages, and industrial and social condition of the North-Western Tribes of the Dominion of Canada; that Mr. Bloxam be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Dr. Garson, Mr. Pengelly, Mr. F. W. Rudler, Mr. G. W. Bloxam, Mr. J. Theodore Bent, and Mr. J. Stuart Glennie be reappointed a Committee for the purpose of investigating the Prehistoric Race in the Greek Islands; that Mr. Bloxam be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That General Pitt-Rivers, Dr. Beddoe, Professor Flower, Mr. Francis Galton, Dr. E. B. Tylor, and Dr. Garson be reappointed a Committee for the purpose of editing a new edition of 'Anthropological Notes and Queries'; that Dr. Garson be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

Not involving Grants of Money.

That Mr. John Murray, Professor Chrystal, Dr. A. Buchan, Rev. C. J. Steward, the Hon. R. Abercromby, Mr. J. Y. Buchanan, Mr. David

Cunningham, Mr. Isaac Roberts, Dr. H. R. Mill, and Professor Fitzgerald be a Committee for the purpose of arranging an investigation of the seasonal variations of temperature in lakes, rivers, and estuaries in various parts of the United Kingdom in co-operation with the Local Societies represented on the Association, and that Mr. John Murray be the Secretary.

That Lord Rayleigh, Professors Rowland, Liveing, Dewar, Everett, W. Grylls Adams, J. J. Thomson, and Schuster, and Messrs. Marshall Watts, and Glazebrook be a Committee for the purpose of taking such steps as may lead to the adoption of an International Scale of Wave-lengths for the Solar Spectrum; and that Professor Schuster be the Secretary.

That Sir F. J. Bramwell, Mr. E. A. Cowper, Mr. G. J. Symons, Professor G. H. Darwin, Professor Ewing, Mr. Isaac Roberts, Mr. Thomas Gray, Dr. John Evans, Professor Lebour, Professor Prestwich, Professor Hull, Professor Meldola, Professor Judd, and Mr. J. Glaisher be a Committee for the purpose of considering the advisability and possibility of establishing in other parts of the country observations upon the prevalence of Earth Tremors, similar to those now being made in Durham in connection with Coal-mine Explosions; and that Professor Lebour be the Secretary.

That Professor Barrett, Professor Fitzgerald, Professor Balfour Stewart, and Mr. Trouton be reappointed a Committee for the purpose of reporting on certain Molecular Phenomena connected with the Magnetisation of Iron; and that Professor Barrett be the Secretary.

That Mr. John Murray, Professor Schuster, Sir William Thomson, the Abbé Renard, Mr. A. Buchan, the Hon. R. Abercrombie, and Dr. M. Grabham be reappointed a Committee for the purpose of investigating the practicability of collecting and identifying Meteoric Dust, and of considering the question of undertaking regular observations in various localities; and that Mr. John Murray be the Secretary.

That Professors A. Johnson, Macgregor, J. B. Cherriman, and H. J. Bovey, and Mr. C. Carpmael be reappointed a Committee for the purpose of promoting Tidal Observations in Canada; and that Professor Johnson be the Secretary.

That Professor Cayley, Sir William Thomson, Mr. James Glaisher, and Mr. J. W. L. Glaisher (Secretary) be reappointed a Committee for the purpose of calculating certain tables in the Theory of Numbers connected with the divisors of a number.

That Professor G. H. Darwin, Sir W. Thomson, and Major Baird be a Committee for the purpose of preparing instructions for the practical work of Tidal Observation; and that Professor Darwin be the Secretary.

That Professor Sylvester, Professor Cayley, and Professor Salmon be reappointed a Committee for the purpose of calculating Tables of the Fundamental Invariants of Algebraic Forms; and that Professor Cayley be the Secretary.

That Professors Everett and Sir William Thomson, Mr. G. J. Symons, Sir A. C. Ramsay, Dr. A. Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Professor Prestwich, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, and Mr. A. Strahan be reappointed a Committee for the purpose of investigating the Rate of Increase of Underground Temperature down-

wards in various Localities of Dry Land and under Water; and that Professor Everett be the Secretary.

That Professor G. H. Darwin and Professor J. C. Adams be reappointed a Committee for the Harmonic Analysis of Tidal Observations; and that Professor Darwin be the Secretary.

That Professors Ramsay, Tilden, Marshall, and W. L. Goodwin be a Committee for the purpose of investigating certain Physical Constants of Solution, especially the expansion of saline solutions; and that Professor W. L. Goodwin be the Secretary.

That Professors Tilden, McLeod, Pickering, and Ramsay, and Drs. Young, A. R. Leeds, and Nicol be a Committee for the purpose of reporting on the Bibliography of Solution; and that Dr. Nicol be the Secretary.

That Captain Abney, General Festing, and Professors W. N. Hartley and H. E. Armstrong be a Committee for the purpose of investigating the Absorption Spectra of Pure Compounds; and that Professor Armstrong be the Secretary.

That Sir H. E. Roscoe, Mr. Lockyer, Professors Dewar, Liveing, Schuster, W. N. Hartley, and Wolcott Gibbs, Captain Abney, and Dr. Marshall Watts be a Committee for the purpose of preparing a new series of Wave-length Tables of the Spectra of the Elements; and that Dr. Marshall Watts be the Secretary.

That Dr. W. T. Blanford, Professor J. W. Judd, Mr. W. Carruthers, Dr. H. Woodward, and Mr. J. S. Gardner be reappointed a Committee for the purpose of reporting on the Fossil Plants of the Tertiary and Secondary Beds of the United Kingdom; and that Mr. Gardner be the secretary.

That Dr. H. Woodward, Mr. H. Keeping, and Mr. J. S. Gardner be reappointed a Committee for the purpose of exploring the Higher Eocene Beds of the Isle of Wight; and that Mr. J. S. Gardner be the Secretary.

That Professor T. G. Bonney, Mr. J. J. H. Teall, and Professor J. F. Blake be reappointed a Committee for the purpose of investigating the Microscopic Structure of the older Rocks of Anglesey; and that Professor J. F. Blake be the Secretary.

That Mr. R. Etheridge, Dr. H. Woodward, and Professor T. R. Jones be reappointed a Committee for the purpose of reporting on the Fossil Phyllopoda of the Palæozoic Rocks; and that Professor T. R. Jones be the Secretary.

That Professor Valentine Ball, Mr. H. G. Fordham, Professor Haddon, Professor Hillhouse, Mr. John Hopkinson, Dr. Macfarlane, Professor Milnes Marshall, Mr. F. T. Mott (Secretary), Dr. Traquair, and Dr. H. Woodward be reappointed a Committee for the purpose of preparing a Report upon the Provincial Museums of the United Kingdom; and that Mr. Mott be the Secretary.

That Sir Joseph D. Hooker, Sir John Lubbock, Sir George Nares, General J. T. Walker, Sir Leopold McClintock, Admiral Sir George H. Richards, Professor Flower, Professor Huxley, Dr. Sclater, Professor Moseley, Mr. John Murray, General Strachey, and Sir William Thomson be reappointed a Committee for the purpose of drawing attention to the desirability of prosecuting further research in the Antarctic Regions; and that Admiral Sir Erasmus Ommanney be the Secretary.

That Dr. J. H. Gladstone, Professor Armstrong, Mr. S. Bourne, Miss Becker, Sir J. Lubbock, Dr. Crosskey, Sir R. Temple, Sir H. E. Roscoe,

Mr. J. Heywood, and Professor N. Story Maskelyne be reappointed a Committee for the purpose of continuing the inquiries relating to the teaching of Science in Elementary Schools; and that Dr. J. H. Gladstone be the Secretary.

That Sir John Lubbock, Dr. John Evans, Professor Boyd Dawkins, Dr. R. Munro, Mr. Pengelly, Dr. Hicks, Mr. J. W. Davis, Professor Meldola, and Dr. Muirhead be reappointed a Committee for the purpose of ascertaining and recording the localities in the British Islands in which Evidences of the Existence of Prehistoric Inhabitants of the Country are found; and that Mr. J. W. Davis be the Secretary.

That the Corresponding Societies Committee, consisting of Mr. Francis Galton (Chairman), Professor A. W. Williamson, Sir Douglas Galton, Professor Boyd Dawkins, Sir Rawson Rawson, Dr. J. G. Garson, Dr. J. Evans, Mr. J. Hopkinson, Professor R. Meldola (Secretary), Mr. W. Whitaker, Mr. G. J. Symons, General Pitt-Rivers, Mr. W. Topley, Mr. H. G. Fordham, and Mr. William White, be reappointed.

That Mr. W. N. Shaw be requested to draw up a Report on the present state of our knowledge in Electrolysis and Electrochemistry.

That Mr. P. T. Main be requested to continue his Report on our experimental knowledge of the Properties of Matter with respect to volume, pressure, temperature, and specific heat.

That Mr. Glazebrook be requested to continue his Report on Optics.

That Professor J. J. Thomson be requested to continue his Report on Electircal Theories.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

Sir W. Thomson's paper 'On the Vortex Theory of the Luminiferous Æther.'

Professor H. Lamb's paper 'On the Theory of Electrical Endosmose and Allied Phenomena, and on the existence of a Sliding Coefficient for a Fluid in contact with a Solid.'

Mr. W. Topley's paper 'On Gold and Silver: their Geological Distribution and their probable Future Production.'

Mr. G. Auldjo Jamieson's paper entitled 'Recent Illustrations of the Theory of Rent and their Effect on the Value of Land,' and a Memorandum 'On the Methods of Ascertaining Variation in the Value of the Precious Metals.'

Professor Osborne Reynolds's paper 'On certain Laws relating to the Régime of Estuaries and on the possibility of Experiments on a small scale' (with the necessary illustrations).

Messrs. E. A. Cowper and W. Anderson's paper 'On the Mechanical Equivalent of Heat' (with the necessary illustrations).

Mr. G. Forbes's paper 'On an Electric Current Meter' (with the necessary illustrations).

Resolutions referred to the Council for Consideration, and Action if desirable.

That the Council be requested to take such action as they may think most expedient in order to bring before the Signal Office of the United States a statement of the high value which British meteorologists attach to the manuscript bibliography prepared by the Signal Office.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Manchester Meeting in August and September 1887. *The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics and Physics.

	£	s.	d.
*Brown, Professor Crum.—Ben Nevis Observatory	150	0	0
*Foster, Professor G. Carey.—Electrical Standards	80	0	0
*Stewart, Professor Balfour.—Magnetic Observations	15	0	0
*Forbes, Professor G.—Standards of Light	100	0	0
*Armstrong, Professor.—Electrolysis	50	0	0
*Stewart, Professor Balfour.—Solar Radiation	10	0	0
Walker, General.—Differential Gravity Meters	10	0	0
Ball, Sir R. S.—Uniform Nomenclature in Mechanics	10	0	0

Chemistry.

*McLeod, Professor.—The Influence of the Silent Discharge of Electricity on Gases	10	0	0
*Tilden, Professor.—Properties of Solutions	25	0	0
Dewar, Professor.—Recording Water Analysis Results	10	0	0
*Tilden, Professor.—Influence of Silicon on Steel	20	0	0
Armstrong, Professor.—Methods of Teaching Chemistry	10	0	0
*Tilden, Professor.—Isomeric Naphthalene Derivatives	25	0	0
Russell, Dr.—Oxidation of Hydracids in Sunlight	20	0	0

Geology.

Davis, Mr. J. W.—Sea Beach near Bridlington	20	0	0
*Evans, Dr. J.—Geological Record	50	0	0
*Etheridge, Mr. R.—'Manure' Gravels of Wexford	10	0	0
*Grantham, Mr. R. B.—Erosion of Sea Coasts	15	0	0
*Prestwich, Professor J.—Erratic Blocks	10	0	0
*Hull, Professor E.—Circulation of Underground Waters	5	0	0
Woodward, Dr. H.—Palæontographical Society Monographs	50	0	0
*Etheridge, Mr. R.—Volcanic Phenomena of Japan	50	0	0
Etheridge, Mr. R.—Pliocene Molluscan Fauna of St. Erth	50	0	0
*Williamson, Professor W. C.—Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
*Bauerman, Mr. H.—Volcanic Phenomena of Vesuvius	20	0	0
Carried forward	£605	0	0

* Reappointed.

	£	s.	d.
Brought forward	605	0	0
Biology.			
Newton, Professor.—Zoology and Botany of the West India Islands	100	0	0
Carruthers, Mr. W.—Flora of the Bahamas	100	0	0
McIntosh, Professor.—Development of Fishes, St. Andrews	50	0	0
*Lankester, Professor E. Ray.—Marine Laboratory, Plymouth	100	0	0
*Cordeaux, Mr. J.—Migration of Birds	30	0	0
*Thiselton-Dyer, Mr.—Flora of China	75	0	0
*Lankester, Professor E. Ray.—Naples Zoological Station	100	0	0
Schäfer, Professor.—Physiology of the Lymphatic System	25	0	0
*McKendrick, Professor.—Marine Station, Granton	50	0	0
*Foster, Professor.—Peradeniya Botanical Station	50	0	0
Lankester, Professor.—Development of the Oviduct in Teleostei	15	0	0
Geography.			
*Walker, General J. T.—Depth of Frozen Soil	5	0	0
Economic Science and Statistics.			
Bourne, Mr. S.—Precious Metals in Circulation	20	0	0
*Bourne, Mr. S.—Variations in the Value of the Monetary Standard	10	0	0
Mechanical Science.			
Reynolds, Professor O.—Investigation of Estuaries by Means of Models	200	0	0
Anthropology.			
Rawson, Sir R.—Effect of Occupations on Physical Development	25	0	0
*Tylor, Dr. E. B.—North-Western Tribes of Canada	100	0	0
*Garson, Dr.—Prehistoric Race in the Greek Islands	20	0	0
*Pitt-Rivers, General.—Anthropological Notes and Queries	50	0	0
	£1975	0	0

* Reappointed.

The Annual Meeting in 1888.

The Meeting at Bath will commence on Wednesday, September 5.

Place of Meeting in 1889.

The Annual Meeting of the Association will be held at Newcastle-on-Tyne.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	103	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	171	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	166	16	6
Animal Secretions	10	10	0
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0

	£	s.	d.
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	5	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854 .... £ 75 0 0; 1855 .... £500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0

	£	s.	d.
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0

	£	s.	d.
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	29	0	0

	£	s.	d.
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0

	£	s.	d.
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat..............................	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee............	25	0	0
Zoological Record...............	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood...............	7	2	6
British Rainfall..................	50	0	0
Kent's Hole Explorations ...	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee............	75	0	0
Zoological Record...............	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab...........	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration...	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood...............	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta ...	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths.........	20	0	0
British Rainfall..................	100	0	0
Poisonous Substances Antagonism.............................	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record..............	100	0	0
Chemistry Record...............	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration ...	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall..................	100	0	0
Essential Oils....................	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations...	25	0	0
Underground Temperature ...	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland............	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors...............	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record..............	100	0	0
Chemistry Record...............	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions...............	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration...	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall..................	100	0	0
Essential Oils....................	10	0	0
Sub-Wealden Explorations ...	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetization of Iron	20	0	0
Marine Organisms...............	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-Measures.......................	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetization of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record...............	100	0	0

	£	s.	d.
Specific Volume of Liquids...	25	0	0
Estimation of Potash and Phosphoric Acid..............	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations ...	100	0	0
Kent's Cavern Exploration...	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record...............	100	0	0
Instructions for Travellers ...	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall..................	100	0	0
Ohm's Law.........................	9	15	0
Tide Calculating Machine ...	200	0	0
Specific Volume of Liquids...	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate..........................	5	0	0
Estimation of Potash and Phosphoric Acid..............	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record..............	100	0	0
Kent's Cavern Exploration ...	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland......	1	10	0
Zoological Record...............	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station...............	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles......	13	15	0
Measuring Speed of Ships ...	10	0	0
Effect of Propeller on turning of Steam Vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acids in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record...............	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpæ, Report on......	20	0	0
Mechanical Equivalent of Heat............................	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperatures	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Elasticity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid..............	1	18	0
Geological Record...............	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c................	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record...............	100	0	0
Investigation of Pulse Phenomena by means of Syphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters..........................	15	0	0
Transmission of Electrical Impulses through Nerve Structure.......................	30	0	0
Calculation of Factor Table of Fourth Million	100	0	0
Anthropometric Committee...	66	0	0
Chemical Composition and Structure of less known Alkaloids........................	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors...............	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland ...	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0

	£	s.	d.
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Circulation of Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature	20	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station	50	0	0
Naples Zoological Station	75	0	0
Natural History of Socotra	50	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
Electrical Standards	25	0	0
Anthropological Notes and Queries	9	0	0
Specific Refractions	7	3	1
	£476	3	1

1882.

	£	s.	d.
Tertiary Flora of North of Ireland	20	0	0
Exploration of Caves of South of Ireland	10	0	0
Fossil Plants of Halifax	15	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Record of Zoological Literature	100	0	0
British Polyzoa	10	0	0
Naples Zoological Station	80	0	0
Natural History of Timor-laut	100	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Natural History of Socotra	100	0	0
Circulation of Underground Waters	15	0	0
Migration of Birds	15	0	0
Earthquake Phenomena of Japan	25	0	0

	£	s.	d.
Geological Map of Europe ...	25	0	0
Elimination of Nitrogen by Bodily Exercise..............	50	0	0
Anthropometric Committee...	50	0	0
Photographing Ultra-Violet Spark Spectra	25	0	0
Exploration of Raygill Fissure	20	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements..............	50	0	0
Geological Record..............	100	0	0
Standards for Electrical Measurements	100	0	0
Exploration of Central Africa	100	0	0
Albuminoid Substances of Serum	10	0	0
	£1126	1	11

1883.

	£	s.	d.
Natural History of Timor-laut	50	0	0
British Fossil Polyzoa	10	0	0
Circulation of Underground Waters..........................	15	0	0
Zoological Literature Record	100	0	0
Exploration of Mount Kilima-njaro...................... .	500	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Fossil Plants of Halifax	0	0	0
Elimination of Nitrogen by Bodily Exercise..............	38	3	3
Isomeric Naphthalene Derivatives.........................	15	0	0
Zoological Station at Naples	80	0	0
Investigation of Loughton Camp	10	0	0
Earthquake Phenomena of Japan	50	0	0
Meteorological Observations on Ben Nevis	50	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Migration of Birds	20	0	0
Geological Record..............	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Scottish Zoological Station ...	25	0	0
Screw Gauges.....................	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Zoological Literature Record	100	0	0
Fossil Polyzoa....................	10	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Anthropometric Committee...	10	0	0
Fossil Plants of Halifax	15	0	0
International Geological Map	20	0	0
Erratic Blocks of England ...	10	0	0
Natural History of Timor-laut	50	0	0
Coagulation of Blood...........	100	0	0
Naples Zoological Station ...	80	0	0
Bibliography of Groups of Invertebrata	50	0	0
Earthquake Phenomena of Japan	75	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Meteorological Observatory at Chepstow.......................	25	0	0
Migration of Birds..............	20	0	0
Collecting and Investigating Meteoric Dust..................	20	0	0
Circulation of Underground Waters..........................	5	0	0
Ultra-Violet Spark Spectra ...	8	4	0
Tidal Observations..............	10	0	0
Meteorological Observations on Ben Nevis	50	0	0
	£1173	4	0

1885.

	£	s.	d.
Zoological Literature Record.	100	0	0
Vapour Pressures, &c., of Salt Solutions........................	25	0	0
Physical Constants of Solutions............................	20	0	0
Recent Polyzoa	10	0	0
Naples Zoological Station ...	100	0	0
Exploration of Mount Kilimanjaro	25	0	0
Fossil Plants of British Tertiary and Secondary Beds .	50	0	0
Calculating Tables in Theory of Numbers....................	100	0	0
Exploration of New Guinea...	200	0	0
Exploration of Mount Roraima	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Meteoric Dust	70	0	0
Marine Biological Station at Granton	100	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Migration of Birds	30	0	0
Synoptic Chart of Indian Ocean	50	0	0
Circulation of Underground Waters..........................	10	0	0
Geological Record	50	0	0
Reduction of Tidal Observations............................	10	0	0
Earthquake Phenomena of Japan	70	0	0
Raygill Fissure	15	0	0
	£1385	0	0

1886.	£	s.	d.
Zoological Literature Record	100	0	0
Exploration of New Guinea	150	0	0
Secretion of Urine	10	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Electrical Standards	40	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Naples Zoological Station	50	0	0
Meteorological Observations on Ben Nevis	100	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Regulation of Wages under Sliding Scales	10	0	0
Exploration of Caves in North Wales	25	0	0
Migration of Birds	30	0	0
Geological Record	100	0	0
Chemical Nomenclature	5	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Solar Radiation	9	10	6
Magnetic Observations	10	10	0
Tidal Observations	50	0	0
Marine Biological Station at Granton	75	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
	£995	0	6

1887.	£	s.	d.
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Standards of Light (1886 grant)	20	0	0
Silent Discharge of Electricity	20	0	0
Exploration of Cae Gwyn Cave, North Wales	20	0	0
Investigation of Lymphatic System	25	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Plymouth Biological Station	50	0	0
Naples Biological Station	100	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Regulation of Wages	10	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Ben Nevis Observatory	75	0	0
Prehistoric Race of Greek Islands	20	0	0
Flora and Fauna of the Cameroons	75	0	0
Provincial Museum Reports	5	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Coal Plants of Halifax	25	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Magnetic Observations	26	2	0
'Manure' Gravels of Wexford	10	0	0
Electrolysis	30	0	0
Fossil Phyllopoda	20	0	0
Racial Photographs, Egyptian	20	0	0
Standards of Light (1887 grant)	10	0	0
Migration of Birds	30	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Electrical Standards	50	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Absorption Spectra	40	0	0
Solar Radiation	18	10	0
Circulation of Underground Waters	5	0	0
Erratic Blocks	10	0	0
	£1186	18	0

General Meetings.

On Wednesday, August 31, at 8 P.M., in the Free Trade Hall, Principal Sir J. William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S., resigned the office of President to Sir H. E. Roscoe, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S., who took the Chair, and delivered an Address, for which see page 1.

On Thursday, September 1, at 7.30 P.M., a Soirée took place at the Royal Jubilee Exhibition.

On Friday, September 2, at 8.30 P.M., in the Free Trade Hall, Professor H. B. Dixon, M.A., F.R.S., delivered a Discourse on 'The Rate of Explosions in Gases.'

On Monday, September 5, at 8.30 P.M., in the Free Trade Hall, Colonel Sir Francis de Winton, K.C.M.G., F.R.G.S., delivered a Discourse on 'Explorations in Central Africa.'

On Tuesday, September 6, at 7.30 P.M., a Soirée took place in the Town Hall.

On Wednesday, September 7, at 2.30 P.M., in the Chemistry Lecture Theatre, Owens College, the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific purposes were explained to the Members.

The Meeting was then adjourned to Bath. [The Meeting is appointed to commence on Wednesday, September 5, 1888.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

SIR HENRY E. ROSCOE,

M.P., D.C.L., LL.D., PH.D., F.R.S., V.P.C.S.,

PRESIDENT.

MANCHESTER, distinguished as the birthplace of two of the greatest discoveries of modern science, heartily welcomes to-day for the third time the members and friends of the British Association for the Advancement of Science.

On the occasion of our first meeting in this city in the year 1842 the President, Lord Francis Egerton, commenced his address with a touching allusion to the veteran of science, John Dalton, the great chemist, the discoverer of the laws of chemical combination, the framer of the atomic theory upon which the modern science of chemistry may truly be said to be based. Lord Francis Egerton said: 'Manchester is still the residence of one whose name is uttered with respect wherever science is cultivated, who is here to-night to enjoy the honours due to a long career of persevering devotion to knowledge, and to receive from myself, if he will condescend to do so, the expression of my own deep personal regret that increase of years, which to him up to this hour has been but increase of wisdom, should have rendered him in respect of mere bodily strength unable to fill on this occasion an office which in his case would have received more honour than it could confer. I do regret that any cause should have prevented the present meeting in his native town from being associated with the name'—and here I must ask you to allow me to exchange the name of Dalton in 1842 for that of Joule in 1887, and to add again in the words of the President of the former year that I would gladly have served as a doorkeeper in any house where Joule, the father of science in Manchester, was enjoying his just pre-eminence.

For it is indeed true that the mantle of John Dalton has fallen on the shoulders of one well worthy to wear it, one to whom science owes a debt

of gratitude not less than that which it willingly pays to the memory of the originator of the atomic theory. James Prescott Joule it was who, in his determination of the mechanical equivalent of heat, about the very year of our first Manchester meeting, gave to the world of science the results of experiments which placed beyond reach of doubt or cavil the greatest and most far-reaching scientific principle of modern times, namely, that of the conservation of energy. This, to use the words of Tyndall, is indeed a generalisation of conspicuous grandeur fit to take rank with the principle of gravitation, more momentous, if that be possible, combining as it does the energies of the material universe into an organic whole, and enabling the eye of science to follow the flying shuttles of the universal power as it weaves what the Erdgeist in 'Faust' calls 'the living garment of God.'

It is well, therefore, for us to remember, in the midst of the turmoil of our active industrial and commercial life, that Manchester not only well represents the energy of England in these practical directions, but that it possesses even higher claims to our regard and respect as being the seat of discoveries of which the value not only to pure science is momentous, but which also lie at the foundation of all our material progress and all our industrial success. For without a knowledge of the laws of chemical combination all the marvellous results with which modern industrial chemistry has astonished the world could not have been achieved, whilst the knowledge of the quantitative relations existing between the several forms of energy, and the possibility of expressing their amount in terms of ordinary mechanics, are matters which now constitute the life-breath of every branch of applied science. For example, before Dalton's discovery every manufacturer of oil of vitriol—a substance now made each week in thousands of tons within a few miles of this spot—every manufacturer had his own notions of the quantity of sulphur which he ought to burn in order to make a certain weight of sulphuric acid, but he had no idea that only a given weight of sulphur can unite with a certain quantityof oxygen and of water to form the acid, and that an excess of any one of the component parts was not only useless but harmful. Thus, and in tens of thousands of other instances, Dalton replaced rule of thumb by scientific principle. In like manner the applications of Joule's determination of the mechanical equivalent of heat are even more general; the increase and measurement of the efficiency of our steam engines and the power of our dynamos are only two of the numerous examples which might be adduced of the practical value of Joule's work.

If the place calls up these thoughts, the time of our meeting also awakens memories of no less interest, in the recollection that we this year celebrate the Jubilee of her Most Gracious Majesty's accession to the throne. It is right that the members of the British Association for the Advancement of Science should do so with heart and voice, for although science requires and demands no royal patronage, we thereby express the feeling which must be uppermost in the hearts of all men of

science, the feeling of thankfulness that we have lived in an age which has witnessed an advance in our knowledge of nature, and a consequent improvement in the physical and, let us trust, also in the moral and intellectual well-being of the people hitherto unknown; an age with which the name of Victoria will ever be associated.

To give even a sketch of this progress, to trace even in the merest outline the salient points of the general history of science during the fifty momentous years of her Majesty's reign, is a task far beyond my limited powers. It must suffice for me to point out to you, to the best of my ability, some few of the steps of that progress as evidenced in the one branch of science with which I am most familiar, and with which I am more closely concerned, the science of chemistry.

In the year 1837 chemistry was a very different science from that existing at the present moment. Priestley, it is true, had discovered oxygen, Lavoisier had placed the phenomena of combustion on their true basis, Davy had decomposed the alkalis, Faraday had liquefied many of the gases, Dalton had enunciated the laws of chemical combination by weight, and Gay Lussac had pointed out the fact that a simple volumetric relation governs the combination of the gases. But we then possessed no knowledge of chemical dynamics, we were then altogether unable to explain the meaning of the heat given off in the act of chemical combination. The atomic theory was indeed accepted, but we were as ignorant of the mode of action of the atoms and as incapable of explaining their mutual relationship as were the ancient Greek philosophers. Fifty years ago, too, the connection existing between the laws of life, vegetable and animal, and the phenomena of inorganic chemistry, was ill understood. The idea that the functions of living beings are controlled by the same forces, chemical and physical, which regulate the changes occurring in the inanimate world, was then one held by only a very few of the foremost thinkers of the time. Vital force was a term in everyone's mouth, an expression useful, as Goethe says, to disguise our ignorance, for

> Wo die Begriffe fehlen,
> Da stellt ein Wort zur rechten Zeit sich ein.

Indeed the pioneer of the chemistry of life, Liebig himself, cannot quite shake himself free from the bonds of orthodox opinion, and he who first placed the phenomena of life on a true basis cannot trust his chemical principles to conduct the affairs of the body, but makes an appeal to vital force to help him out of his difficulties; as when in the body politic an unruly mob requires the presence and action of physical force to restrain it and to bring its members under the saving influence of law and order, so too, according to Liebig's views, in the body corporeal a continual conflict between the chemical forces and the vital power occurs throughout life, in which the latter, when it prevails, insures health and a continuance of life, but of which defeat insures disease or death. The picture presented to the student of to-day is a very different one. We now believe that no

such conflict is possible, but that life is governed by chemical and physical forces, even though we cannot in every case explain its phenomena in terms of these forces; that whether these tend to continue or to end, existence depends upon their nature and amount, and that disease and death are as much a consequence of the operation of chemical and physical laws as are health and life.

Looking back again to our point of departure fifty years ago, let us for a moment glance at Dalton's labours, and compare his views and those of his contemporaries with the ideas which now prevail. In the first place it is well to remember that the keystone of his atomic theory lies not so much in the idea of the existence and the indivisible nature of the particles of matter—though this idea was so firmly implanted in his mind that, being questioned on one occasion on the subject, he said to his friend the late Mr. Ransome, 'Thou knowst it must be so, for no man can split an atom'—as in the assumption that the weights of these particles are different. Thus whilst each of the ultimate particles of oxygen has the same weight as every other particle of oxygen, and each atom of hydrogen, for example, has the same weight as every other particle of hydrogen, the oxygen atom is sixteen times heavier than that of hydrogen, and so on for the atoms of every chemical element, each having its own special weight. It was this discovery of Dalton, together with the further one that the elements combine in the proportions indicated by the relative weights of their atoms or in multiples of these proportions, which at once changed chemistry from a qualitative to a quantitative science, making the old invocation prophetic, 'Thou hast ordered all things in measure and number and weight.'

The researches of chemists and physicists during the last fifty years have not only strengthened but broadened the foundations of the great Manchester philosopher's discoveries. It is true that his original numbers, obtained by crude and inaccurate methods, have been replaced by more exact figures, but his laws of combination and his atomic explanation of those laws stand as the great bulwarks of our science.

On the present occasion it is interesting to remember that within a stone's-throw of this place is the small room belonging to our Literary and Philosophical Society which served Dalton as his laboratory. Here with the simplest of all possible apparatus—a few cups, penny ink bottles, rough balances, and self-made thermometers and barometers—Dalton accomplished his great results. Here he patiently worked, marshalling facts to support his great theory, for as an explanation of his laborious experimental investigations the wise old man says: 'Having been in my progress so often misled, by taking for granted the results of others, I have determined to write as little as possible but what I can attest by my own experience.' Nor ought we, when here assembled, to forget that the last three of Dalton's experimental essays—one of which, on a new method of measuring water of crystallisation, contained more than the germ of a great discovery—were communicated to our Chemical Section

in 1842, and that this was the last memorable act of his scientific life. In this last of his contributions to science, as in his first, his method of procedure was that which has been marked out as the most fruitful by almost all the great searchers after nature's secrets, namely the assumption of a certain view as a working hypothesis, and the subsequent institution of experiment to bring this hypothesis to a test of reality upon which a legitimate theory is afterwards to be based. 'Dalton,' as Henry well says, 'valued detailed facts mainly, if not solely, as the stepping-stones to comprehensive generalisations.'

Next let us ask what light the research of the last fifty years has thrown on the subject of the Daltonian atoms: first, as regards their size; secondly, in respect to their indivisibility and mutual relationships; and thirdly, as regards their motions.

As regards the size and shape of the atoms, Dalton offered no opinion, for he had no experimental grounds on which to form it, believing that they were inconceivably small and altogether beyond the grasp of our senses aided by the most powerful appliances of art. He was in the habit of representing his atoms and their combinations diagrammatically as round discs or spheres made of wood, by means of which he was fond of illustrating his theory. But such mechanical illustrations are not without their danger, for I well remember the answer given by a pupil to a question on the atomic theory: 'Atoms are round balls of wood invented by Dr. Dalton.' So determinedly indeed did he adhere to his mechanical method of representing the chemical atoms and their combinations that he could not be prevailed upon to adopt the system of chemical formulæ introduced by Berzelius and now universally employed. In a letter addressed to Graham in April 1837 he writes: 'Berzelius' symbols are horrifying. A young student in chemistry might as soon learn Hebrew as make himself acquainted with them.' And again: 'They appear to me equally to perplex the adepts in science, to discourage the learner, as well as to cloud the beauty and simplicity of the atomic theory.'

But modern research has accomplished, as regards the size of the atom, at any rate to a certain extent, what Dalton regarded as impossible. Thus in 1865 Loschmidt, of Vienna, by a train of reasoning which I cannot now stop to explain, came to the conclusion that the diameter of an atom of oxygen or nitrogen was $\frac{1}{10,000,000}$ of a centimetre. With the highest known magnifying power we can distinguish the $\frac{1}{40,000}$ part of a centimetre; if now we imagine a cubic box each of whose sides has the above length, such a box when filled with air will contain from 60 to 100 millions of atoms of oxygen and nitrogen. A few years later William Thomson extended the methods of atomic measurement, and came to the conclusion that the distance between the centres of contiguous molecules is less than $\frac{1}{5,000,000}$ and greater than $\frac{1}{1,000,000,000}$ of a centimetre; or, to put it in language more suited to the ordinary mind, Thomson asks us to imagine a drop of water magnified up to the size of the earth, and then tells us that the coarseness of the graining of such a mass would be

something between a heap of small shot and a heap of cricket-balls. Or again, to take Clifford's illustration, you know that our best microscopes magnify from 6,000 to 8,000 times; a microscope which would magnify that result as much again would show the molecular structure of water. Or again, to put it in another form, if we suppose that the minutest organism we can now see were provided with equally powerful microscopes, these beings would be able to see the atoms.

Next, as to the indivisibility of the atom, involving also the question as to the relationships between the atomic weights and properties of the several elementary bodies.

Taking Dalton's aphorism, 'Thou knowst no man can split an atom,' as expressing the view of the enunciator of the atomic theory, let us see how far this idea is borne out by subsequent work. In the first place, Thomas Thomson, the first exponent of Dalton's generalisation, was torn by conflicting beliefs until he found peace in the hypothesis of Prout, that the atomic weights of all the so-called elements are multiples of a common unit, which doctrine he sought to establish, as Thorpe remarks, by some of the very worst quantitative determinations to be found in chemical literature, though here I may add that they were not so incorrect as Dalton's original numbers.

Coming down to a somewhat later date, Graham, whose life was devoted to finding what the motion of an atom was, freed himself from the bondage of the Daltonian aphorism, and defined the atom not as a thing which cannot be divided, but as one which has not been divided. With him, as with Lucretius, as Angus Smith remarks, the original atom may be far down.

But speculative ideas respecting the constitution of matter have been the scientific relaxation of many minds from olden time to the present. In the mind of the early Greek the action of the atom as one substance taking various forms by unlimited combinations was sufficient to account for all the phenomena of the world. And Dalton himself, though upholding the indivisibility of his ultimate particles, says: 'We do not know that any of the bodies denominated elementary are absolutely indecomposable.' Again Boyle, treating of the origin of form and quality, says: 'There is one universal matter common to all bodies—an extended divisible and impenetrable substance.' Then Graham in another place expresses a similar thought when he writes: 'It is conceivable that the various kinds of matter now recognised as different elementary substances may possess one and the same ultimate or atomic molecules existing in different conditions of movement. The essential unity of matter is an hypothesis in harmony with the equal action of gravity upon all bodies.'

What experimental evidence is now before us bearing upon these interesting speculations? In the first place, then, the space of fifty years has completely changed the face of the inquiry. Not only has the number of distinct well-established elementary bodies increased from fifty-three in

1837 to seventy in 1887 (not including the *twenty* or more new elements recently said to have been discovered by Krüss and Nilson in certain rare Scandinavian minerals), but the properties of these elements have béen studied, and are now known to us with a degree of precision then undreamt of. So that relationships existing between these bodies which fifty years ago were undiscernible are now clearly manifest, and it is to these relationships that I would for a moment ask your attention. I have already stated that Dalton measured the relative weights of the ultimate particles by assuming hydrogen as the unit, and that Prout believed that on this basis the atomic weights of all the other elements would be found to be multiples of the atomic weight of hydrogen, thus indicating that an intimate constitutional relation exists between hydrogen and all the other elements.

Since the days of Dalton and Prout the truth or otherwise of Prout's law has been keenly contested by the most eminent chemists of all countries. The inquiry is a purely experimental one, and only those who have a special knowledge of the difficulties which surround such inquiries can form an idea of the amount of labour and self-sacrifice borne by such men as Dumas, Stas, and Marignac in carrying out delicate researches on the atomic weights of the elements. What is, then, the result of these most laborious experiments? It is that, whilst the atomic weights of the elements are not exactly either multiples of the unit or of half the unit, many of the numbers expressing most accurately the weight of the atom approximate so closely to a multiple of that of hydrogen that we are constrained to admit that these approximations cannot be a mere matter of chance, but that some reason must exist for them. What that reason is, and why a close approximation and yet something short of absolute identity exists, is as yet hidden behind the veil; but who is there that doubts that when this Association celebrates its centenary this veil will have been lifted and this occult but fundamental question of atomic philosophy shall have been brought into the clear light of day?

But these are by no means all the relationships which modern science has discovered with respect to the atoms of our chemical elements. So long ago as 1829 Döbereiner pointed out that certain groups of elements exist presenting in all their properties strongly marked family characteristics, and this was afterwards extended and insisted upon by Dumas. We find, for example, in the well-known group of chlorine, bromine, and iodine, these resemblances well developed, accompanied moreover by a proportional graduation in their chemical and physical properties. Thus, to take the most important of all their characters, the atomic weight of the middle term is the mean of the atomic weights of the two extremes. But these groups of triads appeared to be unconnected in any way with one another, nor did they seem to bear any relation to the far larger number of the elements not exhibiting these peculiarities.

Things remained in this condition until 1863, when Newlands threw fresh light upon the subject showing a far-reaching series of relation-

ships. For the first time we thus obtained a glance into the mode in which the elements are connected together, but, like so many new discoveries, this did not meet with the recognition which we now see it deserves. But whilst England thus had the honour of first opening up this new path, it is to Germany and to Russia that we must look for the consummation of the idea. Germany, in the person of Lothar Meyer, keeps, as it is wont to do, strictly within the limits of known facts. Russia, in the person of Mendelejeff, being of a somewhat more imaginative nature, not only seizes the facts which are proved, but ventures upon prophecy. These chemists, amongst whom Carnelley must be named, agree in placing all the elementary bodies in a certain regular sequence, thus bringing to light a periodic recurrence of analogous chemical and physical properties, on account of which the arrangement is termed the periodic system of the elements.

In order to endeavour to render this somewhat complicated matter clear to you, I may perhaps be allowed to employ a simile. Let us, if you please, imagine a series of human families, a French one, represented by Dumas, an English one, by name Newlands, a German one, the family of Lothar Meyer, and lastly a Russian one, that of Mendelejeff. Let us next imagine the names of these chemists placed in a horizontal line in the order I have mentioned. Then let us write under each the name of his father, and again, in the next lower line, that of his grandfather, followed by that of his great-grandfather, and so on. Let us next write against each of these names the number of years which has elapsed since the birth of the individual. We shall then find that these numbers regularly increase by a definite amount, *i.e.*, by the average age of a generation, which will be approximately the same in all the four families. Comparing the ages of the chemists themselves we shall observe certain differences, but these are small in comparison with the period which has elapsed since the birth of any of their ancestors. Now each individual in this series of family trees represents a chemical element; and just as each family is distinguished by certain idiosyncrasies, so each group of the elementary bodies thus arranged shows distinct signs of consanguinity.

But more than this, it not unfrequently happens that the history and peculiarities of some member of a family may have been lost, even if the memory of a more remote and more famous ancestor may be preserved, although it is clear that such an individual must have had an existence. In such a case Francis Galton would not hesitate from the characteristics of the other members to reproduce the physical and even the mental peculiarities of the missing member; and should genealogical research bring to light the true personal appearance and mental qualities of the man, these would be found to coincide with Galton's estimate.

Such predictions and such verifications have been made in the case of no less than three of our chemical elements. Thus, Mendelejeff pointed out that if, in the future, certain lacunæ in his table were to be filled, they must be filled by elements possessing chemical and physical pro-

perties which he accurately specified. Since that time these gaps have actually been stopped by the discovery of Gallium by Lecoq de Boisbaudron, of Scandium by Nilson, and of Germanium by Winkler, and their properties, both physical and chemical, as determined by their discoverers, agree absolutely with those predicted by the Russian chemist. Nay, more than this, we not unfrequently have had to deal with chemical foundlings, elements whose parentage is quite unknown to us. A careful examination of the personality of such waifs has enabled us to restore them to the family from which they have been separated by an unkind fate, and to give them that position in chemical society to which they are entitled.

These remarkable results, though they by no means furnish a proof of the supposition already referred to, viz., that the elements are derived from a common source, clearly point in this direction, and lend some degree of colour to the speculations of those whose scientific imagination, wearying of dry facts, revels in picturing to itself an elemental Bathybius, and in applying to the inanimate, laws of evolution similar to those which rule the animate world. Nor is there wanting other evidence regarding this inquiry, for here heat, the great analyser, is brought into court. The main portion of the evidence consists in the fact that distinct chemical individuals capable of existence at low temperatures are incapable of existence at high ones, but split up into new materials possessing a less complicated structure than the original. And here it may be well to emphasise the distinction which the chemist draws between the atom and the molecule, the latter being a more or less complicated aggregation of atoms, and especially to point out the fundamental difference between the question of separating the atoms in the molecule and that of splitting up the atom itself. The decompositions above referred to are, in fact, not confined to compound bodies, for Victor Meyer has proved in the case of iodine that the molecule at high temperatures is broken to atoms, and J. J. Thomson has added to our knowledge by showing that this breaking up of the molecule may be effected not only by heat vibrations, but likewise by the electrical discharge at a comparatively low temperature.

How far, now, has this process of simplification been carried? Have the atoms of our present elements been made to yield? To this a negative answer must undoubtedly be given, for even the highest of terrestrial temperatures, that of the electric spark, has failed to shake any one of these atoms in two. That this is the case has been shown by the results with which spectrum analysis, that new and fascinating branch of science, has enriched our knowledge, for that spectrum analysis does give us most valuable aid in determining the varying molecular conditions of matter is admitted by all. Let us see how this bears on the question of the decomposition of the elements, and let us suppose for a moment that certain of our present elements, instead of being distinct substances, were made up of common ingredients, and that these compound elements, if I may be allowed to use so incongruous a term, are split up at the temperature of the electric spark into less complicated molecules. Then

the spectroscopic examination of such a body must indicate the existence of these common ingredients by the appearance in the spark spectra of these elements of identical bright lines. Coincidences of this kind have indeed been observed, but on careful examination these have been shown to be due either to the presence of some one of the other elements as an impurity or to insufficient observational power. This absence of coincident lines admits, however, of two explanations—either that the elements are not decomposed at the temperature of the electric spark, or, what appears to me a much more improbable supposition, each one of the numbers of bright lines exhibited by every element indicates the existence of a separate constituent, no two of this enormous number being identical.

Terrestrial analysis having thus failed to furnish favourable evidence, we are compelled to see if any information is forthcoming from the chemistry of the sun and stars. And here I would remark that it is not my purpose now to dilate on the wonders which this branch of modern science has revealed. It is sufficient to remind you that chemists thus have the means placed at their disposal of ascertaining with certainty the presence of elements well known on this earth in fixed stars so far distant that we are now receiving the light which emanated from them perhaps even thousands of years ago.

Since Bunsen and Kirchhoff's original discovery in 1859, the labours of many men of science of all countries have largely increased our knowledge of the chemical constitution of the sun and stars, and to no one does science owe more in this direction than to Lockyer and Huggins in this country, and to Young in the New England beyond the seas. Lockyer has of late years devoted his attention chiefly to the varying nature of the bright lines seen under different conditions of time and place on the solar surface, and from these observations he has drawn the inference that the matching observed by Kirchhoff between, for instance, the iron lines as seen in our laboratories and those visible in the sun, has fallen to the ground. He further explains this want of uniformity by the fact that at the higher transcendental temperatures of the sun the substance which we know here as iron is resolved into separate components. Other experimentalists, however, while accepting Lockyer's facts as to the variations in the solar spectrum, do not admit his conclusions, and would rather explain the phenomena by the well-known differences which occur in the spectra of all the elements when their molecules are subject to change of temperature or change of position.

Further, arguments in favour of this idea of the evolution of the elements have been adduced from the phenomena presented by the spectra of the fixed stars. It is well known that some of these shine with a white, others with a red, and others again with a blue light; and the spectroscope, especially under the hands of Huggins, has shown that the chemical constitution of these stars is different. The white stars, of which Sirius may be taken as a type, exhibit a much less complicated spectrum than the orange and the red stars; the spectra of the latter

remind us more of those of the metalloids and of chemical compounds than of the metals. Hence it has been argued that in the white, presumably the hottest, stars a celestial dissociation of our terrestrial elements may have taken place, whilst in the cooler stars, probably the red, combination even may occur. But even in the white stars we have no *direct* evidence that a decomposition of any terrestrial atom has taken place; indeed we learn that the hydrogen atom, as we know it here, can endure unscathed the inconceivably fierce temperature of stars presumably many times more fervent than our sun, as Sirius and Vega.

Taking all these matters into consideration, we need not be surprised if the earthbound chemist should, in the absence of celestial evidence which is incontestable, continue, for the present at least, and until fresh evidence is forthcoming, to regard the elements as the unalterable foundation stones upon which his science is based.

Pursuing another line of inquiry on this subject, Crookes has added a remarkable contribution to the question of the possibility of decomposing the elements. With his well-known experimental prowess, he has discovered a new and beautiful series of phenomena, and has shown that the phosphorescent lights emitted by certain chemical compounds, especially the rare earths, under an electric discharge in a high vacuum exhibit peculiar and characteristic lines. For the purpose of obtaining his material Crookes started from a substance believed by chemists to be homogeneous, such, for example, as the rare earth yttria, and succeeded by a long series of fractional precipitations in obtaining products which yield different phosphorescent spectra, although when tested by the ordinary methods of what we may term high temperature spectroscopy, they appear to be the one substance employed at the starting point. The other touchstone by which the identity, or otherwise, of these various products might be ascertained, viz., the determination of their atomic weights, has not, as yet, engaged Crookes' attention. In explanation of these singular phenomena, the discoverer suggests two possibilities. First, that the bodies yielding the different phosphorescent spectra are different elementary constituents of the substance which we call yttria. Or, if this be objected to because they all yield the same spark spectrum, he adopts the very reasonable view that the Daltonian atom is probably, as we have seen, a system of chemical complexity; and adds to this the idea that these complex atoms are not all of exactly the same constitution and weight, the differences, however, being so slight that their detection has hitherto eluded our most delicate tests, with the exception of this one of phosphorescence in a vacuum. To these two explanations, Marignac, in a discussion of Crookes' results, adds a third. It having been shown by Crookes himself that the presence of the minutest traces of foreign bodies produces remarkable alterations in the phosphorescent spectra, Marignac suggests that in the course of the thousands of separations which must be made before these differences become manifest, traces of foreign bodies may have been accidentally introduced, or, being present

in the original material, may have accumulated to a different extent in the various fractions, their presence being indicated by the only test by which they can now be detected. Which of these three explanations is the true one must be left to future experiment to decide.

We must now pass from the statics to the dynamics of chemistry; that is, from the consideration of the atoms at rest to that of the atoms in motion. Here again we are indebted to John Dalton for the first step in this direction, for he showed that the particles of a gas are constantly flying about in all directions; that is, that gases diffuse into one another, as an escape of coal gas from a burner, for example, soon makes itself perceptible throughout the room. Dalton, whose mind was constantly engaged in studying the molecular condition of gases, first showed that a light gas cannot rest upon a heavier gas as oil upon water, but that an interpenetration of each gas by the other takes place. It is, however, to Graham's experiments, made rather more than half a century ago, that we are indebted for the discovery of the law regulating these molecular motions of gases, proving that their relative rates of diffusion are inversely proportional to the square roots of their densities, so that oxygen being 16 times heavier than hydrogen, their relative rates of diffusion are 1 and 4.

But whilst Dalton and Graham indicated that the atoms are in a continual state of motion, it is to Joule that we owe the first accurate determination of the rate of that motion. At the Swansea Meeting in 1848, Joule read a paper before Section A on the Mechanical Equivalent of Heat and on the Constitution of Elastic Fluids. In this paper Joule remarks that whether we conceive the particles to be revolving round one another according to the hypothesis of Davy, or flying about in every direction according to Herapath's view, the pressure of the gas will be in proportion to the *vis viva* of its particles. 'Thus it may be shown that the particles of hydrogen at the barometrical pressure of 30 inches at a temperature of 60° must move with a velocity of 6225·54 feet per second in order to produce a pressure of 14·714 lbs. on the square inch;' or, to put it in other words, a molecular cannonade or hailstorm of particles, at the above rate—a rate, we must remember, far exceeding that of a cannon ball—is maintained against the bounding surface.

We can, however, go a step further and calculate with Clerk Maxwell the number of times in which this hydrogen molecule, moving at the rate of 70 miles per minute, strikes against others of the vibrating swarm, and we learn that in one second of time it must knock against others no less than 18 thousand million times.

And here we may pause and dwell for a moment on the reflection that in nature there is no such thing as great or small, and that the structure of the smallest particle, invisible even to our most searching vision, may be as complicated as that of any one of the heavenly bodies which circle round our sun.

But how does this wonderful atomic motion affect our chemistry? Can chemical science or chemical phenomena throw light upon this

motion, or can this motion explain any of the known phenomena of our science? I have already said that Lavoisier left untouched the dynamics of combustion. He could not explain why a fixed and unalterable amount of heat is in most cases emitted but in some cases absorbed when chemical combination takes place. What Lavoisier left unexplained Joule has made clear. On August 25, 1843, Joule read a short communication, I am glad to remember, before the Chemical Section of our Association, meeting that year at Cork, containing an announcement of a discovery which was to revolutionise modern science. This consisted in the determination of the mechanical equivalent of heat, in proving by accurate experiment that the expenditure of energy equal to that developed by the weight of 772 pounds falling through one foot at Manchester, the temperature of one pound of water can be raised 1° Fahrenheit. In other words, every change in the arrangement of the particles is accompanied by a definite evolution or an absorption of heat. In all such cases the molecular energy leaves the potential to assume the kinetic form, or *vice versâ*. Heat is evolved by the clashing of the atoms, and this amount is fixed and definite.

Thus it is to Joule we owe the foundation of chemical dynamics and the basis of thermal chemistry. As the conservation of mass or the principle of the indestructibility of matter forms the basis of chemical statics, so the principle of the conservation of energy[1] constitutes the foundation of chemical dynamics. Change in the form of matter and change in the form of energy are the universal accompaniments of every chemical operation. Here again it is to Joule we owe the proof of the truth of this principle in another direction, viz., that when electrical energy is developed by chemical change a corresponding quantity of chemical energy disappears. Energy as defined by Maxwell is the power of doing work, and work is the act of producing a change of configuration in a system in opposition to a force which resists that change. Chemical action produces such a change of configuration in the molecules. Hence, as Maxwell says, 'a complete knowledge of the mode in which the potential energy of a system varies with the configuration would enable us to predict every possible motion of the system under the action of given external forces, provided we were able to overcome the purely mathematical difficulties of the calculation.' The object of thermal chemistry is to measure these changes of energy by thermal methods, and to connect these with chemical changes, to estimate the attractions of the atoms and molecules to which the name of chemical affinity has been applied, and thus to solve the most fundamental problem of chemical science. How far has modern research approached the solution of this most difficult problem? How far can we answer the question,

[1] 'The total energy of any material system is a quantity which can neither be increased nor diminished by any action between the parts of the system, though it may be transformed into any of the forms of which energy is susceptible.'—MAXWELL.

what is the amount of the forces at work in these chemical changes? What laws govern these forces? Well, even in spite of the results with which recent researches, especially the remarkable ones of the Danish philosopher Thomsen have enriched us, we must acknowledge that we are yet scarcely in sight of Maxwell's position of successful prediction. Thermal chemistry, we must acknowledge, is even yet in its infancy; it is, however, an infant of sturdy growth, likely to do good work in the world, and to be a credit to him who is its acknowledged father, as well as to those who have so carefully tended it in its early years.

But recent investigation in another direction bids fair even to eclipse the results which have been obtained by the examination of thermal phenomena. And this lies in the region of electrical chemistry. Faraday's work relating to conductivity of chemical substances has been already referred to, and this has been since substantiated and extended to pure substances by Kohlrausch. It has been shown, for example, that the resistance of absolutely pure water is almost an infinite quantity. But a small quantity of an acid, such as acetic or butyric acid, greatly increases the conductivity; but more than this, it is possible by determination of the conductivity of a mixture of water with these two acids to arrive at a conclusion as to the partition of the molecules of the water between the acids. Such a partition, however, implies a change of position, and therefore we are furnished with a means of recognising the motion of the molecules in a liquid, and of determining its amount. Thus it has been found that the hindrance to molecular motion is more affected by the chemical character of the liquid than by physical characters such as viscosity. We have seen that chemical change is always accompanied by molecular motion, and further evidence of the truth of this is gained from the extraordinary chemical inactivity of pure unmixed substances. Thus pure anhydrous hydrochloric acid does not act upon lime, whereas the addition of even a trace of moisture sets up a most active chemical change, and hundreds of other examples of a similar kind might be stated. Bearing in mind that these pure anhydrous compounds do not conduct, we are led to the conclusion that an intimate relation exists between chemical activity and conductivity. And we need not stop here; for a method is indicated indeed by which it will be possible to arrive at a measure of chemical affinity from determination of conductivity. It has indeed been already shown that the rate of change in the saponification of acetic ether is directly proportional to the conductivity of the liquid employed.

Such wide-reaching inquiries into new and fertile fields, in which we seem to come into nearer touch with the molecular state of matter, and within a measurable distance of accurate mathematical expression, leads to confident hope that Lord Rayleigh's pregnant words at Montreal may ere long be realised: 'It is from the further study of electrolysis that we may expect to gain improved views as to the nature of chemical reactions, and of the forces concerned in bringing them about; and I cannot help

thinking that the next great advance, of which we already have some foreshadowing, will come on this side.'

There is, perhaps, no branch of our science in which the doctrine of the Daltonian atom plays a more conspicuous part than in organic chemistry or the chemistry of the carbon compounds, as there is certainly none in which such wonderful progress has been made during the last fifty years. One of the most striking and perplexing discoveries made rather more than half a century ago was that chemical compounds could exist which, whilst possessing an identical chemical composition, that is containing the same percentage quantity of their constituents, are essentially distinct chemical substances exhibiting different properties. Dalton was the first to point out the existence of such substances, and to suggest that the difference was to be ascribed to a different or to a multiple arrangement of the constituent atoms. Faraday soon afterwards proved that this supposition was correct, and the research of Liebig and Wöhler on the identity of composition of the salts of fulminic and cyanic acid gave further confirmation to the conclusion, leading Faraday to remark that 'now we are taught to look for bodies composed of the same elements in the same proportion but differing in their qualities, they may probably multiply upon us.' How true this prophecy has become we may gather from the fact that we now know of thousands of cases of this kind, and that we are able not only to explain the reason of their difference by virtue of the varying position of the atoms within the molecule, but even to predict the number of distinct variations in which any given chemical compound can possibly exist. How large this number may become will be understood from the fact that, for example, one chemical compound, a hydrocarbon containing thirteen atoms of carbon combined with twenty-eight atoms of hydrogen, can be shown to be capable of existing in no less than 802 distinct forms.

Experiment in every case in which it has been applied has proved the truth of such a prediction, so that the chemist has no need to apply the cogent argument sometimes said to be used by experimentalists enamoured of pet theories, 'When facts do not agree with theory, so much the worse for the facts!' This power of successful prediction constitutes a high-water mark in science, for it indicates that the theory upon which such a power is based is a true one.

But if the Daltonian atom forms the foundation of this theory, it is upon a knowledge of the mode of arrangement of these atoms and on a recognition of their distinctive properties that the superstructure of modern organic chemistry rests. Certainly it does appear almost to verge on the miraculous that chemists should now be able to ascertain with certainty the relative position of atoms in a molecule so minute that millions upon millions, like the angels in the schoolmen's discussion, can stand on a needle's point. And yet this process of orientation is one which is accomplished every day in our laboratories, and one which more than any other has led to results of a startling character. Still, this

sword to open the oyster of science would have been wanting to us if we had not taken a step farther than Dalton did, in the recognition of the distinctive nature of the elemental atoms. We now assume on good grounds that the atom of each element possesses distinct capabilities of combination; some a single capability, others a double, others a triple, and others again a fourfold combining capacity. The germs of this theory of valency, one of the most fruitful of modern chemical ideas, were ennunciated by Frankland in 1852, but the definite explanation of the linking of atoms, of the tetrad nature of the carbon atoms, their power of combination, and of the difference in structure between the fatty and aromatic series of compounds, was first pointed out by Kekulé in 1857; though we must not forget that this great principle was foreshadowed so long ago as 1833 from a physical point of view by Faraday in his well-known laws of electrolysis, and that it is to Helmholtz in his celebrated Faraday lecture that we owe the complete elucidation of the subject; for, whilst Faraday has shown that the number of the atoms electrolytically deposited is in the inverse ratio of their valencies, Helmholtz has explained this by the fact that the quantity of electricity with which each atom is associated is directly proportional to its valency.

Amongst the tetrad class of elements, carbon, the distinctive element of organic compounds, finds its place; and the remarkable fact that the number of carbon compounds far exceeds that of all the other elements put together receives its explanation. For these carbon atoms not only possess four means of grasping other atoms, but these four-handed carbon atoms have a strong partiality for each other's company, and readily attach themselves hand in hand to form open chains or closed rings to which the atoms of other elements join to grasp the unoccupied carbon hand, and thus to yield a dancing company in which all hands are locked together. Such a group, each individual occupying a given position with reference to the others, constitutes the organic molecule. When, in such a company, the individual members change hands, a new combination is formed. And as in such an assembly the eye can follow the changing positions of the individual members, so the chemist can recognise in his molecule the position of the several atoms, and explain by this the fact that each arrangement constitutes a new chemical compound possessing different properties, and account in this way for the decompositions which each differently constituted molecule is found to undergo.

Chemists are, however, not content with representing the arrangement of the atoms in one plane, as on a sheet of paper, but attempt to express the position of the atoms in space. In this way it is possible to explain certain observed differences in isomeric bodies which otherwise baffled our efforts. To Van t'Hoff, in the first instance, and more recently to Wislicenus, chemistry is indebted for work in this direction, which throws light on hitherto obscure phenomena, and points the way to still further and more important advances.

It is this knowledge of the mode in which the atoms in the molecule are arranged, this power of determining the nature of this arrangement,

which has given to organic chemistry the impetus which has overcome so many experimental obstacles, and given rise to such unlooked-for results. Organic chemistry has now become synthetic. In 1837 we were able to build up but very few and very simple organic compounds from their elements; indeed the views of chemists were much divided as to the possibility of such a thing. Both Gmelin and Berzelius argued that organic compounds, unlike inorganic bodies, cannot be built up from their elements. Organic compounds were generally believed to be special products of the so-called vital force, and it was only intuitive minds, like those of Liebig and Wöhler, who foresaw what was coming, and wrote in 1837 strongly against this view, asserting that the artificial production in our laboratories of all organic substances, so far as they do not constitute a living organism, is not only probable but certain. Indeed, they went a step farther, and predicted that sugar, morphia, salicine, will all thus be prepared; a prophecy which, I need scarcely remind you, has been after fifty years fulfilled, for at the present time we can prepare an artificial sweetening principle, an artificial alkaloid, and salicine.

In spite of these predictions, and in spite of Wöhler's memorable discovery in 1828 of the artificial production of urea, which did in reality break down for ever the barrier of essential chemical difference between the products of the inanimate and of the animate world, still, even up to a much later date, contrary opinions were held, and the synthesis of urea was looked upon as the exception which proves the rule. So it came to pass that for many years the artificial production of any of the more complicated organic substances was believed to be impossible. Now the belief in a special vital force has disappeared like the *ignis fatuus*, and no longer lures us in the wrong direction. We know now that the same laws regulate the formation of chemical compounds in both animate and inanimate nature, and the chemist only asks for a knowledge of the constitution of any definite chemical compound found in the organic world in order to be able to promise to prepare it artificially.

But the progress of synthetic organic chemistry, which has of late been so rapid, was made in the early days of the half-century only by feeble steps and slow. Seventeen long years elapsed between Wöhler's discovery and the next real synthesis. This was accomplished by Kolbe, who in 1845 prepared acetic acid from its elements. But then a splendid harvest of results gathered in by chemists of all nations quickly followed, a harvest so rich and so varied that we are apt to be overpowered by its wealth, and amidst so much that is alluring and striking we may well find it difficult to choose the most appropriate examples for illustrating the power and the extent of modern chemical synthesis.

Next, as a contrast to our picture, let us for a moment glance back again to the state of things fifty years ago, and then notice the chief steps by which we have arrived at our present position. In 1837 organic chemistry possessed no scientific basis, and therefore no classification of a character worthy of the name. Writing to Berzelius in that year, Wöhler

describes the condition of organic chemistry as one enough to drive a man mad. 'It seems to me,' says he, 'like the tropical forest primæval, full of the strangest growths, an endless and pathless thicket in which a man may well dread to wander.' Still clearances had already been made in this wilderness of facts. Berzelius in 1832 welcomed the results of Liebig and Wöhler's research on benzoic acid as the dawn of a new era; and such it really was, inasmuch as it introduced a novel and fruitful idea, namely the possibility of a group of atoms acting like an element by pointing out the existence of organic radicals. This theory was strengthened and confirmed by Bunsen's classical researches on the cacodyl compounds, in which he showed that a common group of elements, which acts exactly as a metal, can exist in the free state, and this was followed soon afterwards by isolation of the so-called alcohol radicals by Frankland and Kolbe. It is, however, to Schorlemmer that we owe our knowledge of the true constitution of these bodies, a matter which proved to be of vital importance for the further development of the science.

Turning our glance in another direction we find that Dumas, in 1834, by his law of substitution threw light upon a whole series of singular and unexplained phenomena by showing that an exchange can take place between the constituent atoms in a molecule. Laurent indeed went farther, and assumed that a chlorine atom, for example, took up the position vacated by an atom of hydrogen and played the part of its displaced rival, so that the chemical and physical properties of the substitution-product were thought to remain substantially the same as those of the original body. A singular story is connected with this discovery. At a soirée in the Tuileries in the time of Charles X. the guests were almost suffocated by acrid vapours which were evidently emitted by the burning wax candles, and the great chemist Dumas was called in to examine into the cause of the annoyance. He found that the wax of which the candles were made had been bleached by chlorine, that a replacement of some of the hydrogen atoms of the wax by chlorine had occurred, and that the suffocating vapours consisted of hydrochloric acid given off during the combustion. The wax was as white and as odourless as before, and the fact of the substitution of chlorine for hydrogen could only be recognised when the candles were destroyed by burning. This incident induced Dumas to investigate more closely this class of phenomena, and the results of this investigation are embodied in his law of substitution. So far indeed did the interest of the French school of chemists lead them that some assumed that not only the hydrogen but also the carbon of organic bodies could be replaced by substitution. Against this idea Liebig protested, and in a satirical vein he informs the chemical public, writing from Paris under the *nom de plume* of S. Windler, that he has succeeded in substituting not only the hydrogen but the oxygen and carbon in cotton cloth by chlorine, and he adds that the London shops are now selling nightcaps and other articles of apparel made entirely of chlorine, goods which meet with much favour, especially for hospital use!

But the debt which chemistry, both inorganic and organic, thus owes to Dumas' law of substitution is serious enough, for it proved to be the germ of Williamson's classical researches on etherefication, as well as of those of Wurtz and Hofmann on the compound ammonias, investigations which lie at the base of the structure of modern chemistry. Its influence has been, however, still more far-reaching, inasmuch as upon it depends in great measure the astounding progress made in the wide field of organic synthesis.

It may here be permitted to me to sketch in rough outline the principles upon which all organic syntheses have been effected. We have already seen that as soon as the chemical structure of a body has been ascertained its artificial preparation may be certainly anticipated, so that the first step to be taken is the study of the structure of the naturally occurring substance which it is desired to prepare artificially by resolving it into simpler constituents, the constitution of which is already known. In this way, for example, Hofmann discovered that the alkaloid coneine, the poisonous principle of hemlock, may be decomposed into a simpler substance well known to chemists under the name of pyridine. This fact having been established by Hofmann, and the grouping of the atoms approximately determined, it was then necessary to reverse the process, and, starting with pyridine, to build up a compound of the required constitution and properties, a result recently achieved by Ladenburg in a series of brilliant researches. The well-known synthesis of the colouring matter of madder by Graebe and Liebermann, preceded by the important researches of Schunck, and that of indigo by Baeyer, are other striking examples in which this method has been successfully followed.

Not only has this intimate acquaintance with the changes which occur within the molecules of organic compounds been utilised, as we have seen, in the synthesis of naturally occurring substances, but it has also led to the discovery of many new ones. Of these perhaps the most remarkable instance is the production of an artificial sweetening agent termed saccharin, 250 times sweeter than sugar, prepared by a complicated series of reactions from coal-tar. Nor must we imagine that these discoveries are of scientific interest only, for they have given rise to the industry of the coal-tar colours, the value of which is measured by millions sterling annually, an industry which Englishmen may be proud to remember was founded by our countryman Perkin.

Another interesting application of synthetic chemistry to the needs of everyday life is the discovery of a series of valuable febrifuges, amongst which I may mention antipyrin as the most useful. An important aspect in connection with the study of these bodies is the physiological value which has been found to attach to the introduction of certain organic radicals, so that an indication is given of the possibility of preparing a compound which will possess certain desired physiological properties, or even to foretell the kind of action which such bodies may exert on the animal economy.

But it is not only the physiological properties of chemical compounds which stand in intimate relation with their constitution, for we find that this is the case with all their physical properties. It is true that at the beginning of our period any such relation was almost unsuspected, whilst at the present time the number of instances in which this connection has been ascertained is almost infinite. Amongst these perhaps the most striking is the relationship which has been pointed out between the optical properties and chemical composition. This was in the first place recognised by Pasteur in his classical researches on racemic and tartaric acids in 1848; but the first to indicate a quantitative relationship and a connection between chemical structure and optical properties was Gladstone in 1863. Great instrumental precision has been brought to bear on this question, and consequently most important practical applications have resulted. I need only refer to the well-known accurate methods now in everyday use for the determination of sugar by the polariscope, equally valuable to the physician and to the manufacturer.

But now the question may well be put, is any limit set to this synthetic power of the chemist? Although the danger of dogmatising as to the progress of science has already been shown in too many instances, yet one cannot help feeling that the barrier which exists between the organised and unorganised worlds is one which the chemist at present sees no chance of breaking down.

It is true that there are those who profess to foresee that the day will arrive when the chemist, by a succession of constructive efforts, may pass beyond albumen, and gather the elements of lifeless matter into a living structure. Whatever may be said regarding this from other standpoints, the chemist can only say that at present no such problem lies within his province. Protoplasm, with which the simplest manifestations of life are associated, is not a compound, but a structure built up of compounds. The chemist may successfully synthesise any of its component molecules, but he has no more reason to look forward to the synthetic production of the structure than to imagine that the synthesis of gallic acid leads to the artificial production of gall-nuts.

Although there is thus no prospect of our effecting a synthesis of organised material, yet the progress made in our knowledge of the chemistry of life during the last fifty years has been very great, and so much so indeed that the sciences of physiological and of pathological chemistry may be said to have entirely arisen within this period.

In the introductory portion of this address I have already referred to the relations supposed to exist fifty years ago between vital phenomena and those of the inorganic world. Let me now briefly trace a few of the more important steps which have marked the progress of this branch of science during this period. Certainly no portion of our science is of greater interest, nor, I may add, of greater complexity, than that which, bearing on the vital functions both of plants and of animals, endeavours to unravel the tangled skein of the chemistry of life, and to explain the

principles according to which our bodies live, and move, and have their being. If, therefore, in the less complicated problems with which other portions of our science have to deal, we find ourselves, as we have seen, often far from possessing satisfactory solutions, we cannot be surprised to learn that with regard to the chemistry of the living body—whether vegetable or animal—in health or disease we are still farther from a complete knowledge of phenomena, even those of fundamental importance.

It is of interest here to recall the fact that nearly fifty years ago Liebig presented to the Chemical Section of this Association a communication in which, for the first time, an attempt was made to explain the phenomena of life on chemical and physical lines, for in this paper he admits the applicability of the great principle of the conservation of energy to the functions of animals, pointing out that the animal cannot generate more heat than is produced by the combustion of the carbon and hydrogen of his food.

'The source of animal heat,' says Liebig, 'has previously been ascribed to nervous action or to the contraction of the muscles, or even to the mechanical motions of the body, as if these motions could exist without an expenditure of force [equal to that] consumed in producing them.' Again he compares the living body to a laboratory furnace in which a complicated series of changes occur in the fuel, but in which the end-products are carbonic acid and water, the amount of heat evolved being dependent, not upon the intermediate, but upon the final products. Liebig asked himself the question, Does every kind of food go to the production of heat; or can we distinguish, on the one hand, between the kind of food which goes to create warmth, and, on the other, that by the oxidation of which the motions and mechanical energy of the body are kept up? He thought that he was able to do this, and he divided food into two categories; the starchy or carbohydrate food is that, said he, which by its combustion provides the warmth necessary for the existence and life of the body. The albuminous or nitrogenous constituents of our food, the flesh meat, the gluten, the casein out of which our muscles are built up, are not available for the purposes of creating warmth, but it is by the waste of those muscles that the mechanical energy, the activity, the motions of the animal are supplied. We see, said Liebig, that the Esquimaux feeds on fat and tallow, and this burning in his body keeps out the cold. The Gaucho, riding on the pampas, lives entirely on dried meat, and the rowing man and pugilist, trained on beefsteaks and porter, require little food to keep up the temperature of their bodies, but much to enable them to meet the demand for fresh muscular tissue, and for this purpose they need to live on a strongly nitrogenous diet.

Thus far Liebig. Now let us turn to the present state of our knowledge. The question of the source of muscular power is one of the greatest interest, for, as Frankland observes, it is the corner-stone of the physiological edifice and the key to the nutrition of animals.

Let us examine by the light of modern science the truth of Liebig's view—even now not uncommonly held—as to the functions of the two kinds of food, and as to the cause of muscular exercise being the oxidation of the muscular tissue. Soon after the promulgation of these views, J. R. Mayer, whose name as the first expositor of the idea of the conservation of energy is so well known, warmly attacked them, throwing out the hypothesis that all muscular action is due to the combustion of food, and not to the destruction of muscle, proving his case by showing that if the muscles of the heart be destroyed in doing mechanical work the heart would be burnt up in eight days! What does modern research say to this question? Can it be brought to the crucial test of experiment? It can; but how? Well, in the first place we can ascertain the work done by a man or any other animal; we can measure this work in terms of our mechanical standard, in kilogramme-metres or foot-pounds. We can next determine what is the destruction of nitrogenous tissue at rest and under exercise by the amount of nitrogenous material thrown off by the body. And here we must remember that these tissues are never completely burnt, so that free nitrogen is never eliminated. If now we know the heat-value of the burnt muscle, it is easy to convert this into its mechanical equivalent, and thus measure the energy generated. What is the result? Is the weight of muscle destroyed by ascending the Faulhorn or by working on the treadmill sufficient to produce on combustion heat enough when transformed into mechanical exercise to lift the body up to the summit of the Faulhorn or to do the work on the treadmill? Careful experiment has shown that this is so far from being the case that the actual energy developed is twice as great as that which could possibly be produced by the oxidation of the nitrogenous constituents eliminated from the body during twenty-four hours. That is to say, taking the amount of nitrogenous substance cast off from the body, not only whilst the work was being done but during twenty-four hours, the mechanical effect capable of being produced by the muscular tissue from which this cast-off material is derived would only raise the body halfway up the Faulhorn, or enable the prisoner to work half his time on the treadmill.

Hence it is clear that Liebig's proposition is not true. The nitrogenous constituents of the food do doubtless go to repair the waste of muscle, which, like every other portion of the body, needs renewal, whilst the function of the non-nitrogenous food is not only to supply the animal heat, but also to furnish, by its oxidation, the muscular energy of the body.

We thus come to the conclusion that it is the potential energy of the food which furnishes the actual energy of the body, expressed in terms either of heat or of mechanical work.

But there is one other factor which comes into play in this question of mechanical energy, and must be taken into account; and this factor we are as yet unable to estimate in our usual terms. It concerns the action of the mind upon the body, and, although incapable of exact expression, exerts none the less an important influence on the physics and chemistry

of the body, so that a connection undoubtedly exists between intellectual activity or mental work and bodily nutrition. In proof that there is a marked difference between voluntary and involuntary work, we need only compare the mechanical action of the heart, which never causes fatigue, with that of the voluntary muscles, which become fatigued by continued exertion. So, too, we know well that an amount of drill which is fatiguing to the recruit is not felt by the old soldier, who goes through the evolutions automatically. What is the expenditure of mechanical energy which accompanies mental effort, is a question which science is probably far removed from answering. But that the body experiences exhaustion as the result of mental activity is a well-recognised fact. Indeed, whilst the second law of thermodynamics teaches that in none of the mechanical contrivances for the conversion of heat into actual energy can such a conversion be complete, it is perhaps possible, as Helmholtz has suggested, that such a complete conversion may take place in the subtle mechanism of the animal organism.

The phenomena of vegetation, no less than those of the animal world, have, however, during the last fifty years been placed by the chemist on an entirely new basis. Although before the publication of Liebig's celebrated report on chemistry and its application to agriculture, presented to the British Association in 1840, much had been done, many fundamental facts had been established, still Liebig's report marks an era in the progress of this branch of our science. He not only gathered up in a masterly fashion the results of previous workers, but put forward his own original views with a boldness and frequently with a sagacity which gave a vast stimulus and interest to the questions at issue. As a proof of this I may remind you of the attack which he made on, and the complete victory which he gained over, the humus theory. Although Saussure and others had already done much to destroy the basis of this theory, yet the fact remained that vegetable physiologists up to 1840 continued to hold to the opinion that humus, or decayed vegetable matter, was the only source of the carbon of vegetation. Liebig, giving due consideration to the labours of Saussure, came to the conclusion that it was absolutely impossible that the carbon deposited as vegetable tissue over a given area, as for instance over an area of forest land, could be derived from humus, which is itself the result of the decay of vegetable matter. He asserted that the whole of the carbon of vegetation is obtained from the atmospheric carbonic acid, which, though only present in the small relative proportion of 4 parts in 10,000 of air, is contained in such absolutely large quantity that if all the vegetation on the earth's surface were burnt, the proportion of carbonic acid which would thus be thrown into the air would not be sufficient to double the present amount.

That this conclusion of Liebig's is correct needed experimental proof, but such proof could only be given by long-continued and laborious experiment, and this serves to show that chemical research is not now confined to laboratory experiments lasting perhaps a few minutes, but that it has

invaded the domain of agriculture as well as of physiology, and reckons the periods of her observations in the field not by minutes, but by years. It is to our English agricultural chemists Lawes and Gilbert that we owe the complete experimental proof required. And it is true that this experiment was a long and tedious one, for it has taken forty-four years to give the definite reply. At Rothamsted a plot was set apart for the growth of wheat. For forty-four successive years that field has grown wheat without addition of any carbonised manure; so that the only possible source from which the plant could obtain the carbon for its growth is the atmospheric carbonic acid. Now, the quantity of carbon which on an average was removed in the form of wheat and straw from a plot manured only with mineral matter was 1,000 pounds, whilst on another plot, for which a nitrogenous manure was employed, 1,500 pounds more carbon was annually removed; or 2,500 pounds of carbon are removed by this crop annually without the addition of any carbonaceous manure. So that Liebig's prevision has received a complete experimental verification.

May I, without wearying you with experimental details, refer for a moment to Liebig's views as to the assimilation of nitrogen by plants—a much more complicated and difficult question than the one we have just considered—and compare these with the most modern results of agricultural chemistry? We find that in this case his views have not been substantiated. He imagined that the whole of the nitrogen required by the plant was derived from atmospheric ammonia; whereas Lawes and Gilbert have shown by experiments of a similar nature to those just described, and extending over a nearly equal length of time, that this source is wholly insufficient to account for the nitrogen removed in the crop, and have come to the conclusion that the nitrogen must have been obtained either from a store of nitrogenous material in the soil or by absorption of free nitrogen from the air. These two apparently contradictory alternatives may perhaps be reconciled by the recent observations of Warrington and of Berthelot, which have thrown light upon the changes which the so-called nitrogenous capital of the soil undergoes, as well as upon its chemical nature, for the latter has shown that under certain conditions the soil has the power of absorbing the nitrogen of the air, forming compounds which can subsequently be assimilated by the plant.

Touching us as human beings even still more closely than the foregoing, is the influence which chemistry has exerted on the science of pathology, and in no direction has greater progress been made than in the study of micro-organisms in relation to health and disease. In the complicated chemical changes to which we give the names of fermentation and putrefaction, the views of Liebig, according to which these phenomena are of a purely chemical character, have given way under the searching investigations of Pasteur, who established the fundamental principle that these processes are inseparably connected with the life of certain low forms of organisms. Thus was founded the science of bacte-

riology, which in Lister's hands has yielded such splendid results in the treatment of surgical cases; and in those of Klebs, Koch, William Roberts, and others, has been the means of detecting the cause of many diseases both in man and animals; the latest and not the least important of which is the remarkable series of successful researches by Pasteur into the nature and mode of cure of that most dreadful of maladies, hydrophobia. And here I may be allowed to refer with satisfaction to the results of the labours on this subject of a committee, the formation of which I had the honour of moving for in the House of Commons. These results confirm in every respect Pasteur's assertions, and prove beyond a doubt that the adoption of his method has prevented the occurrence of hydrophobia in a large proportion of persons bitten by rabid animals, who, if they had not been subjected to this treatment, would have died of that disease. The value of his discovery is, however, greater than can be estimated by its present utility, for it shows that it may be possible to avert other diseases besides hydrophobia by the adoption of a somewhat similar method of investigation and of treatment. This, though the last, is certainly not the least of the debts which humanity owes to the great French experimentalist. Here it might seem as if we had outstepped the boundaries of chemistry, and have to do with phenomena purely vital. But recent research indicates that this is not the case, and points to the conclusion that the microscopist must again give way to the chemist, and that it is by chemical rather than by biological investigation that the causes of diseases will be discovered, and the power of removing them obtained. For we learn that the symptoms of infective diseases are no more due to the microbes which constitute the infection than alcoholic intoxication is produced by the yeast-cell, but that these symptoms are due to the presence of definite chemical compounds, the result of the life of these microscopic organisms. So it is to the action of these poisonous substances formed during the life of the organism, rather than to that of the organism itself, that the special characteristics of the disease are to be traced; for it has been shown that the disease can be communicated by such poisons in entire absence of living organisms.

If I have thus far dwelt on the progress made in certain branches of pure science it is not because I undervalue the other methods by which the advancement of science is accomplished, viz., that of the application and of the diffusion of a knowledge of nature, but rather because the British Association has always held, and wisely held, that original investigation lies at the root of all application, so that to foster its growth and encourage its development has for more than fifty years been our chief aim and wish.

Had time permitted I should have wished to have illustrated this dependence of industrial success upon original investigation, and to have pointed out the prodigious strides which chemical industry in this country has made during the fifty years of her Majesty's reign. As it is I must be content to remind you how much our modern life, both in its artistic

and useful aspects, owes to chemistry, and, therefore, how essential a knowledge of the principles of the science is to all who have the industrial progress of the country at heart.

This leads me to refer to what has been accomplished in this country of ours towards the diffusion of scientific knowledge amongst the people during the Victorian era. It is true that the English people do not possess, as yet, that appreciation of the value of science so characteristic of some other nations. Up to very recent years our educational system, handed down to us from the middle ages, has systematically ignored science, and we are only just beginning, thanks in a great degree to the prevision of the late Prince Consort, to give it a place, and that but an unimportant one, in our primary and secondary schools or in our universities. The country is, however, now awakening to the necessity of placing its house in order in this respect. and is beginning to see that if she is to maintain her commercial and industrial supremacy the education of her people from top to bottom must be carried out on new lines. The question as to how this can be most safely and surely accomplished is one of transcendent national importance, and the statesman who solves this educational problem will earn the gratitude of generations yet to come.

In conclusion, may I be allowed to welcome the unprecedentedly large number of foreign men of science who have on this occasion honoured the British Association by their presence, and to express the hope that this meeting may be the commencement of an international scientific organisation, the only means nowadays existing, to use the words of one of the most distinguished of our guests, of establishing that fraternity among nations from which politics appears to remove us farther and farther by absorbing human powers and human work, and directing them to purposes of destruction? It would indeed be well if Great Britain, which has hitherto taken the lead in so many things that are great and good, should now direct her attention to the furthering of international organisations of a scientific nature. A more appropriate occasion than the present meeting could perhaps hardly be found for the inauguration of such a movement.

But whether this hope be realised or not, we all unite in that one great object, the search after truth for its own sake, and we all, therefore, may join in re-echoing the words of Lessing: 'The worth of man lies not in the truth which he possesses, or believes that he possesses, but in the honest endeavour which he puts forth to secure that truth; for not by the possession of truth, but by the search after it, are the faculties of man enlarged, and in this alone consists his ever-growing perfection. Possession fosters content, indolence, and pride. If God should hold in His right hand all truth, and in His left hand the ever-active desire to seek truth, though with the condition of perpetual error, I would humbly ask for the contents of the left hand, saying, "Father, give me this; pure truth is only for Thee."'

REPORTS

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Third Report of the Committee, consisting of Professors A. Johnson (*Secretary*), J. G. MacGregor, J. B. Cherriman, *and* H. T. Bovey *and* Mr. C. Carpmael, *appointed for the purpose of promoting Tidal Observations in Canada.*

The Committee have much pleasure in reporting that although a grant for establishing stations for continuous tidal observations has not yet been made by the Dominion Parliament, yet preliminary steps have been taken under the direction of the Minister of Marine (the Hon. G. E. Foster) which point to their early establishment.

At an interview with the minister in May, in which the President of the British Association (Sir J. William Dawson) took part, it was stated that, although the Hudson Bay Expedition had ended, yet another source of expenditure had taken its place, as the Canadian Government had undertaken to pay half the cost of a re-survey of the Gulf of St. Lawrence by the Admiralty. When this work, which would probably occupy two years, was finished, it was hoped that a special grant would be made for systematic tidal observations. Meanwhile, authority had been given to Lieut. Gordon, R.N., commanding one of the Dominion cruisers, to make some preliminary observations, and to spend some small sums of money in getting assistance in making them.

In the course of the interview, the minister said that directions would be given to Lieut. Gordon to put himself in communication with Prof. Darwin. This has since been done.

The Minister of Marine is conscious of the facilities offered in connection with the Association, and by the use of the 'tide-predicter' of the Indian Government, for the reduction of the observations. The importance of the harmonic analysis has been fully dwelt on. Under these encouraging circumstances the Committee consider that the prospects of the speedy establishment of stations for continuous observations are hopeful.

Fourth Report of the Committee, consisting of Professor BALFOUR STEWART (*Secretary*), Professor STOKES, Professor SCHUSTER, Mr. G. JOHNSTONE STONEY, Professor Sir H. E. ROSCOE, Captain ABNEY, *and* Mr. G. J. SYMONS, *appointed for the purpose of considering the best methods of recording the direct Intensity of Solar Radiation.*

IN the last report of this Committee a description was given of a copper enclosure which had been constructed by them.

This consisted of a copper cube $3\frac{1}{2}$ inches square outside, the faces of which were $\frac{5}{8}$ths of an inch thick. The cube was packed round with felt $\frac{9}{10}$ths of an inch thick, and the whole was faced outside with thin polished brass plates.

Thermometers were inserted into that side of the cube intended ultimately to face the sun, and into the opposite side, by means of which the temperature of these sides could be accurately determined. Finally, a thermometer was placed in the vacant space in the very centre of the enclosure.

This last thermometer occupies the position that will ultimately be occupied by the internal thermometer, upon which the sun is to fall through a hole; only at this stage the hole had not been constructed. It is obvious that when the instrument is finally in action, with a beam of solar rays (condensed by means of a lens so as to pass through the hole) falling upon the bulb, this thermometer will be subject to a heating effect from two separate causes.

(*a*) It will, first of all, be subject to radiation and convection from the surrounding enclosure, which is gradually (let us suppose) getting hot through exposure to the sun.

(*b*) It will, secondly, have a beam of solar rays of constant size and of constant intensity (except as to variations arising from atmospheric absorption, seasonal change in the sun's apparent diameter, or change in the sun's intrinsic radiation) continuously thrown upon it through the hole.

In fine days when there is no abrupt variation of the sun's intensity the temperature of the internal thermometer will remain sensibly constant, or at least will only vary slowly with the sun's altitude; and this temperature will be such that the heat lost by radiation and convection from the internal hot thermometer will be equal to the heat which it gains from the sources (*a*) and (*b*), save as to a small correction, calculable from the slow variation of the temperature of the thermometer.

Now, our object being to estimate accurately the intensity of source (*b*), we must be able, notwithstanding the gradual heating of the enclosure, to determine how much heat the internal thermometer gains from source (*a*). That is to say, we must be able to tell what would be the temperature of the internal thermometer if the instrument were still made to face the sun, but without any aperture. For the solid angle subtended by the hole at any point of the bulb is so small that we may regard it as a matter of indifference whether there be a hole or not, except as to the admission or exclusion of direct solar radiation.

It was suggested by Professor Stokes that a simple practical method of doing this would be to expose the instrument, without a hole, to an

artificial source of heat, such as a fire or a stove, the intensity of which might likewise be made to vary. By this means the conditions of the instrument when facing the sun might be fairly represented.

Experiments of this nature were made at Manchester by Mr. Shepherd, acting under the superintendence of Professor Stewart, and these were reduced by Professor Stokes.

It was ascertained from these experiments that the internal thermometer represented with great exactness the temperature of the cube such as it was $3\frac{1}{2}$ minutes before; in other words, there was a lagging time of the internal thermometer equal to $3\frac{1}{2}$ minutes.

We may thus find what would be the reading of the internal thermometer if the balance were perfect between the gain of heat by direct solar radiation and the loss of heat by communication to the environment; and as the latter is approximately proportional to the difference of temperature of the envelope and internal thermometer, and the deviation from exact proportionality admits of determination by laboratory experiments, we have the means of measuring the former. We must bear in mind that the lagging time of the final thermometer may be different from that of the thermometer with which these experiments were made.

It was likewise ascertained that the difference between the temperature of the internal thermometer and that of the case need not exceed 20° Fahr., and that a comparatively small lens and hole would suffice for obtaining this result.

In consequence of this preliminary information, we have made the following additions to the instrument described in our last report:—

(1) We have had it swung like the ordinary actinometers with a motion in altitude and azimuth, and with two moderately delicate adjusting-screws, one for azimuth and another for altitude adjustments.

(2) We have had a thermometer centrically placed in the interior. The graduation of the stem is very delicate, and extends from 20° to 120° Fahr., the reading being taken from one of the sides. The bulb is of green flint, and the stem of colourless glass.

(3) We have also had a small plate of quartz cut and polished and mounted so as to cover the hole, and to be easily removed and replaced. The object of the plate is to prevent irregularities arising from irregular issue of heated air through the hole, entrance of cooler air blown in by wind, &c., and the choice of material was influenced by the wish to permit of frequent cleaning without risk of alteration by scratching.

We ought to mention that as it would be difficult to procure the loan of a good heliostat, and expensive to make one, we resolved that in the preliminary experiments the adjustments to keep the sun's image on the hole should be made by the observer. Hence the necessity for the adjusting-screws already described.

The Committee have expended £18 10*s.*, and return to the Association a balance of £1 10*s.*

They suggest that they should be reappointed, and that the sum of £10 be placed at their disposal to defray the expense of further experiments connected with the instrument.

Report of the Committee, consisting of Professor CRUM BROWN (*Secretary*), Mr. MILNE HOME, Mr. JOHN MURRAY, Lord McLAREN, *and* Mr. BUCHAN, *appointed for the purpose of co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.*

THE observing work by Mr. Omond and his assistants of the Ben Nevis Observatory for the past year has been carried on with the same intelligence, enthusiasm, and completeness as in previous years, none of the hourly observations, by night and by day, inside and outside the observatory having been omitted down to the close of last month, except the outside observations of temperature on two of the hours of December 8, when the weather was too stormy to be faced. The five daily observations at the sea-level station at Fort William have also been made with the greatest regularity.

For the year 1886 the following were the mean pressures and temperatures at the Ben Nevis Observatory and at Fort William:—

Mean Pressures in Inches.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Ben Nevis Observatory	24·944	25·398	25·234	25·273	25·322	25·417	25·319	25·382	25·395	25·266	25·213	24·960	25·260
Fort William	29·544	30·071	29·875	29·864	29·880	29·940	29·810	29·865	29·916	29·780	29·783	29·558	29·824
Difference .	4·600	4·673	4·641	4·591	4·558	4·523	4·491	4·483	4·521	4·514	4·570	4·598	4·564

Mean Temperatures.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	°	°	°	°	°	°	°	°	°	°	°	°	°
Ben Nevis Observatory	19·8	21·1	22·0	26·8	30·5	36·0	38·5	39·9	36·4	34·6	29·5	20·2	29·6
Fort William	35·5	34·8	38·7	44·0	48·2	53·3	55·6	55·3	51·3	49·4	43·7	34·3	45·3
Diff .	15·7	13·7	16·7	17·2	17·7	17·3	17·1	15·4	14·9	14·8	14·2	14·1	15·7

The pressures at Fort William are reduced to 32° and sea level; those at the observatory only to 32°.

With the two exceptions of October and November, the temperature at Fort William was every month below its normal. The extreme departures from the normal were December 4°·7, January 3°·4, and February 3°·9 under, and, on the other hand, October 2°·6 above the normal. The annual mean 45°·3 was 1°·8 below the average of the twenty-four years ending 1880.

Atmospheric pressure at Fort William was very nearly the normal on the mean of the year, being only 0·012 inch under it.

The maximum pressure for the year at the observatory was 26·093 inches on November 24, and the minimum 23·454 inches on December 8, during the memorable storm that swept over the country at that time. A still lower pressure, viz., 23·173 inches, was observed on January 26, 1884, when pressure at 32° and sea level fell at Ochtertyre, Perthshire, to 27·333 inches; and as the centre of this great storm passed only a short way to the south of the observatory, this may be considered as the lowest pressure likely to be noted at the observatory.

The maximum temperature for the year was 55°·8 in September, and the lowest 8°·4 in December, thus giving an absolute range of 47°·4.

The following are the yearly extremes of temperature since the observatory was opened:—

	Maximum	Minimum
1884	° 60·1	° 9·9
1885	60·0	11·1
1886	55·8	8·4
1887 (to August)	67·0	9·0

The most noteworthy feature of these figures is the close approach the annual minima make to each other, the close agreement of the four, and the by no means low temperature they indicate in view of what occurs at lower levels. This may be explained by the observatory being built on the very top of the mountain, thus minimising the effects of terrestrial radiation during the winter months. Previous to June 1887 the highest temperature was 60°·1. But in that month this temperature was several times exceeded, and on the 24th of the month the registering thermometer recorded a maximum of 67°·0. The mean temperature of the month was 45°·4, or 9°·2 higher than that of June 1886. The absolutely lowest temperature was 31°·0, and of July following 30°·8. In these two months, therefore, temperature fell but little below the freezing point, thus indicating for this height in the atmosphere a more prolonged period of relatively high temperature than has taken place since the observatory was founded.

The records of the sunshine recorder commenced in the end of January 1884. As regards the two complete years for which there are now observations, there were 680 hours in 1885 and 576 hours in 1886, being 16 and 14 per cent. of the possible sunshine of these years. From January to July of the present year the percentage of possible sunshine has been 23, a result largely due to the comparatively large amount of sunshine in April, May, and June, which amounted to 31 per cent. of the possible sunshine. Up to May 31, 1887, the largest number of hours of sunshine in any month was 162 in July 1885; but during last June there were 206 hours, or nearly 40 per cent. of the possible sunshine. In July following there were only 58 hours of sunshine, being little more than a fourth of the sunshine of June. The distribution of the sunshine during the hours o 1the day was similar to the results obtained for previous years, as detailed in the Committee's report for last year.

As respects the rain and snowfall, it is desirable to keep in mind that some uncertainty will always necessarily attach to the recorded amounts, owing to the snow-drifts, the breaks that occur in the returns in consequence, and the general uncertainty of the estimates formed for the periods of these breaks.

During 1885 the amount of the rainfall was 146·50 inches, being the first whole year observed; but in 1886, the amount was only 107·84 inches. The amounts for the months of 1886 were, beginning with January, in inches:—12·76, 2·84, 5·91; 4·59, 6·25, 7·60; 10·99, 10·16, 13·03; 8·16, 14·57, 10·98; and for 1887 to July inclusive, 17·80, 13·30, 5·90; 7·53, 3·97, 7·51; and 14·54. The number of days during 1886 on which the precipitation was less than 0·01 inch were 97 days, and from January to July 1887, 87 days. The largest monthly rainfall of these nineteen months was, therefore, 17·80 in January 1887, and the smallest 2·84 inches in

February 1886. The month with the largest number of days on which less than 0·01 inch was recorded was 18 in June last, and the smallest no days in July 1886.

It is expected that the hourly observations, given *in extenso*, of the Ben Nevis Observatory to the end of 1886, and those of the sea-level station at Fort William, referred to in the Committee's last report as in the press as an extra volume of the 'Transactions of the Royal Society of Edinburgh,' will be ready for delivery at the end of the year.

In preparing new isothermal and isobaric charts of the globe for the 'Challenger' Expedition Report, Mr. Buchan has constructed tables of corrections for height above the sea up to 8,000 feet for the different air temperatures and sea-level pressures that occur, which are based on the results arrived at regarding the rate of diminution of temperature, and of pressure with heights for different air temperatures and sea-level pressures. The results of charting from these tables offer the strongest corroboration of the great value in practical meteorology and in physical geography of this piece of work already accomplished from the data furnished by the Ben Nevis and Fort William observations.

In the meantime, and in addition to the regular work of the observatory, Mr. Omond, superintendent; Mr. Rankin, first assistant; and Mr. Dickson, who has repeatedly relieved the regular observers at the observatory, are engaged in carrying on original researches. Of these the following may be mentioned:—

Mr. Omond.—1. A second paper on the rainfall of Ben Nevis in relation to the winds, in which the observations of 1886 are dealt with. The most important result is in corroboration of the results deduced from the observations of 1885, viz., of all winds N.W. winds are much the wettest while they blow; and he can now state explicitly that the rule holds good both as regards cyclonic and anti-cyclonic winds, which is a valuable contribution to the theory of storms.

2. The diurnal variations in the direction of the summer winds on Ben Nevis.

3. On a peculiarity of the cyclone winds of Ben Nevis (which is to be read at the meeting).

4. Glories, halos, and coronæ seen from Ben Nevis Observatory, being in continuation of a paper on the subject published in the 'Proceedings of the Royal Society of Edinburgh' of last year. The new facts brought forward in these papers, for which the observatory affords peculiar facilities for observing, necessitate important modifications of the explanations hitherto given of these phenomena.

5. Temperatures at different heights above ground at Ben Nevis Observatory.

Mr. A. Rankin.—1. The thermic wind-rose at the Ben Nevis Observatory, to be read at the meeting. For the coming year Mr. Rankin has undertaken the laborious work of prosecuting the inquiry still further by sorting the winds and the temperatures in cyclonic and anti-cyclonic areas, and also into the two opposite sides of these areas.

2. He has also recently detected a connection between an increased darkness of one of the lines of the spectrum and a mass of air of an unusually low temperature over the observatory, and no opportunity will be lost next year in accumulating observations bearing on the point.

Mr. Dickson.—1. A continuation of his hygrometric work, to be read at the meeting.

2. Observations on earth-currents in Ben Nevis Observatory telegraph cable.

Copies of these papers so far as published are submitted with this report.

The plotting of the observations of storms made at the whole of the sixty-six Scottish lighthouses, showing graphically the hours of the day and night during which the wind blew with the force of a gale or storm at each lighthouse, is now far advanced; and on the same sheets have been entered for the respective districts all cases where storm signals have been hoisted under direction of the Meteorological Office. The results show a very large number of failures, both of storms which have occurred of which no warning had been sent, and of warnings issued with no accompanying or following storm. These failures are at present being investigated by the Ben Nevis observations in connection with the observations at Fort William and other low-lying stations in that division of Scotland. It is expected that a report of the results of this investigation will be ready to be submitted to the next meeting of the Association.

Arrangements are thus made by the Directors of the observatory for the next twelve months for the investigation, in various directions, of the relations of the Ben Nevis observations to weather, and particularly storms, the workers being Messrs. Omond and Rankin at the observatory, and Messrs. Buchan and Dickson in the office of the Scottish Meteorological Society.

We do not require to inform Section A that we ground our claim on the countenance and assistance of the British Association on the scientific work of the observatory. One is surprised to meet occasionally in the daily press and scientific literature of the day statements to the effect that Ben Nevis is expected of and by itself, and without the help of synchronous low-level observations, to frame warnings of coming storms, and that if this is supposed not to be done, there is no hesitation in adding that the establishment does not deserve public assistance. It is unnecessary to say that this Association has always been conspicuous in never having withheld moral and material support from investigations until it was shown that the results could be turned to practical purposes.

Your Committee, however, from the first, while assuming that the claim of the Observatory for support is the scientific work done by it, have in each of their annual reports expressed their opinion that, as observations accumulate, and as the very laborious discussion of them proceeds, the high expectations they had formed as to the practical value of these high-level observations in forecasting weather and storms have been more than realised.

At last year's meeting at Birmingham it was stated in Section A, as an argument against supporting the Ben Nevis Observatory, that its observations were found to be useless in forecasting weather, but the grounds of this opinion were not given. A single statement will show that any such opinion must rest on imperfect information.

The Directors of the observatory and your Committee in their reports have from the very outset insisted with some earnestness and strength of language on the absolute necessity of combining the double observation for all forecasting purposes—in other words, of combining the observation at the top of Ben Nevis with that made at the same instant at Fort William. The reason is obvious, it being by vertical gradients, and not by horizontal gradients, that the observations at high-level observa-

tories can be turned to their proper and fullest account in forecasting weather.

Now, when the observatory was opened in December 1883 the hours for observation at Fort William were arranged so as to embrace the hours adopted by the Meteorological Office, viz., 8 A.M. and 2 and 6 P.M.; and one of the first acts of the Directors was absolutely to place at the service of the Meteorological Office weather telegrams for these three hours both from the top and bottom of the mountain. This offer was declined on the ground of the expense for the transmission of the telegrams, and until Mr. Buchan shall have thoroughly discussed the observations, and deduced inferences from them from which the Meteorological Office might learn how to use the observations in forecasting weather.

Since, in fact, none of the sea-level observations at Fort William from the founding of the observatory in the end of 1883 down to the present time are in the Meteorological Office, or indeed anywhere but in the office in Edinburgh, the opinion that the Ben Nevis observations are useless in forecasting falls to the ground.

On the evening of August 23 there was a discussion in Parliament on the vote for the Learned Societies, and in that discussion the next morning newspapers reported that Mr. Jackson, of the Treasury, Sir John Lubbock, Sir E. Birkbeck, and others, argued against any grant to the observatory on the ground that the Meteorological Council, composed of men of the very highest scientific standing, had given it as their opinion that the practical results to be obtained from the Ben Nevis Observatory did not warrant the grant asked for from the Treasury.

A word as to this opinion. The Meteorological Council recently printed a memorandum 'On Occasional Telegrams from Ben Nevis,' signed Frederick Gaster, which was forwarded to the Treasury some time before the discussion came on in Parliament. A copy was also sent to the Directors of the observatory by instructions from General Strachey. The memorandum concludes thus: 'In their existing form the telegrams [from Ben Nevis] are absolutely useless.'

The whole question turns on the meaning of the phrase 'their existing form,' which a few sentences will explain.

When in December 1883 the offer of the Directors to send daily telegrams from the top and bottom of the mountain was declined, the Meteorological Office asked instead for occasional telegrams in these words: 'We wish Mr. Omond to use his own discretion, and telegraph to us whenever any very striking change of conditions or a special phenomenon of great interest is recorded.' It will be noted that the Meteorological Office made no mention whatever of storms. Since December 1883 Mr. Omond has sent such telegrams as appeared to him to be wished, and no application has been made for upwards of three years for more frequent telegrams or any other information, only that some time ago a request was forwarded that every effort be made that the telegrams do not exceed the sixpenny charge.

The request, it will be noted, was for telegrams 'whenever any very striking change of conditions' was recorded. Now, as a matter of fact, no telegram has been sent with reference to all those storms, forming the immense majority of storms, which have not been preceded or accompanied by a very striking change of conditions. But, further, several telegrams were sent because it seemed to Mr. Omond that the very

striking change of conditions which occurred *prognosticated settled weather.* Now in drawing up the memorandum for the Treasury all these, as well as the other telegrams sent, were classed together by the Meteorological Office and treated as if they had been intended by Mr. Omond to be prognostic of storms, and the nineteen telegrams sent were assumed to be all the warnings of storms which the observatory could send to the office in London. From these data, so arranged for and collected and interpreted, the decision was come to that 'in their existing form the telegrams from Ben Nevis are absolutely useless.' It might have been predicted before a single telegram was received that no other than such a decision could possibly have been arrived at.

While the statement that 'in their existing form the telegrams are absolutely useless' is thus unquestionably correct, it is nevertheless void of all meaning as respects the matter in hand. What has been done is not an investigation, and it is not science. But the statement underwent a transforming process in its passage to the House of Commons, appearing in this form, viz., 'The Ben Nevis observations are absolutely useless in forecasting weather'—a statement of which it is enough to say that it is incorrect. The Meteorological Office has yet to take the first step towards commencing an investigation into the utility of the Ben Nevis observations for forecasting purposes.

On the other hand the Council of the Scottish Meteorological Society, strengthened as regards the Direction of the observatory by representatives of the Royal Societies of London and Edinburgh and the Philosophical Society of Glasgow, includes men of equal scientific merit with any other Meteorological Council in the country; and after some years' investigation their opinion is that the Ben Nevis observations are of the highest utility in the development of meteorology and in framing forecasts of storms and weather for the British Islands.

Fourth Report of the Committee, consisting of Professor BALFOUR STEWART (*Secretary*), Mr. J. KNOX LAUGHTON, Mr. G. J. SYMONS, Mr. R. H. SCOTT, *and* Mr. G. JOHNSTONE STONEY, *appointed for the purpose of co-operating with* Mr. E. J. LOWE *in his project of establishing on a permanent and scientific basis a Meteorological Observatory near Chepstow.*

THIS Committee met at 22 Albemarle Street on March 26, and passed the following resolution:—

'As your Committee have heard no further results from the action referred to by Mr. Lowe in his letter quoted in their last report, and there thus appears to be an absence of local support, they see no prospect of the scheme ever being carried out. The fundamental idea presiding over the establishment of the observatory was that it should be one of permanence, and hence it is obvious that adequate endowment is essential. To provide this, and properly equip the observatory, several thousand pounds are needed; but the Committee have no assurance that anything at all approaching the necessary amount has yet been subscribed or even promised. As they have now been in existence for between three and

four years with this negative result, they are of opinion that the Committee should now be dissolved.'

In consequence of this resolution the Committee have not drawn the 20*l.* voted at Birmingham, and they do not now request their reappointment.

Final Report of the Committee, consisting of Mr. R. H. SCOTT (*Secretary*), Mr. J. NORMAN LOCKYER, Professor G. G. STOKES, Professor BALFOUR STEWART, *and* Mr. J. G. SYMONS, *appointed in August* 1881, *and re-appointed in* 1882–3 *and* 4 *to co-operate with the Meteorological Society of the Mauritius in the publication of Daily Synoptic Charts of the Indian Ocean for the year* 1861. (*Drawn up by* Mr. ROBERT H. SCOTT.)

YOUR Committee have to report that the sum of 50*l.* originally granted in 1881 has now been expended, and they enclose herewith a receipt for the amount, showing its disposition, from the Treasurer of the Mauritius Meteorological Society.

Dr. Meldrum, in a letter to the Secretary, dated June 4, 1887, says: 'I am requested by the President and Council of our Meteorological Society to convey to yourself and the British Association their very best thanks, and to say that the Society will forward to the Association, through you, two copies of each of the publications that have been issued.'

The following is a list of these publications :—

1. Daily Synoptic Weather Charts of the Indian Ocean for the months of January, February, and March, 1861. The charts for the remaining months of 1861, and remarks to accompany the months already published, are in preparation.

2. Tabular Statements of the number of Gales experienced monthly between the parallels of 20° S. and 46° S., and the meridians of 0° and 120° E. during the last 39 years.

Dr. Meldrum further states that the following works are nearly ready for publication :—

I. Synoptic Weather Charts of the Indian Ocean for January 1860, in the course of which month a typical tropical cyclone took place.

II. The Tracks of the Tropical Cyclones in the Indian Ocean, south of the Equator, from 1848 to 1886, as far as is known, together with the observations from which the tracks have been deduced.

III. The Mean Pressure and Temperature of the Indian Ocean for five degrees square, in the months of January and July.

IV. Synoptic Charts of the Indian Ocean for each day, during the last 39 years, in which it is known that a cyclone existed.

V. The Average Limits in the Indian Ocean of the South-East Trade in each month, and of the North-West Monsoon from November to May.

Second Report of the Committee, consisting of General J. T. WALKER, Sir WILLIAM THOMSON, Sir J. H. LEFROY, General R. STRACHEY, Professors A. S. HERSCHEL, G. CHRYSTAL, C. NIVEN, J. H. POYNTING (*Secretary*), A. SCHUSTER, *and* G. H. DARWIN, *and* Mr. H. TOMLINSON, *appointed for the purpose of inviting designs for a good Differential Gravity Meter in supersession of the pendulum, whereby satisfactory results may be obtained at each station of observation in a few hours, instead of the many days over which it is necessary to extend pendulum observations.*

SINCE the last report the Committee have received an account of a proposed instrument from Mr. C. V. Boys. Mr. Boys has lately found that quartz threads, which he is able to draw from melted quartz, are remarkably free from 'fatigue,' and he intends to make use of this in constructing a torsion gravimeter. In the form which seems to be most promising a quartz thread is stretched horizontally, and to the middle of it is attached one end of an arm going out at right angles with a mass at the other end. The thread is twisted and the arm is drawn out of the horizontal position till it is nearly in unstable equilibrium, and the arrangement is exceedingly sensitive to small changes in the weight of the mass. In principle the instrument resembles other applications of horizontal torsion, such as those in some forms of Sir W. Thomson's attracted disc electrometers. As Mr. Boys is engaged in experimenting on the best form of instrument, we do not give more than the foregoing sketch of his proposals.

As the metal spring which Sir William Thomson proposed to use (described in last year's report) appears to be subject to 'fatigue' in a much greater degree than Mr. Boys's quartz threads, he is awaiting the results of Mr. Boys's experiments before proceeding with the construction of a complete instrument.

The Committee ask for reappointment, with the addition of Mr. Boys, and they apply for a grant of 10*l.* to aid in the construction of an instrument.

Report of the Committee, consisting of Professors WILLIAMSON, ARMSTRONG, DIXON, TILDEN, REINOLD, J. PERRY, O. J. LODGE, BONNEY, STIRLING, BOWER, D'ARCY THOMPSON, *and* MILNES MARSHALL, *and* Messrs. W. H. PREECE, VERNON HARCOURT, CROOKES, TOPLEY, *and* E. F. J. LOVE (*Secretary*), *appointed for the purpose of considering the desirability of combined action for the purpose of Translation of Foreign Memoirs and for reporting thereon.*

THIS Committee have held two meetings, and carefully discussed the subject submitted to it by the British Association. The result of the discussion is expressed in the following resolution of the Committee:—

'That, owing to the difficulty of making suitable selection of the

papers, and in view of the probable heavy cost of such an undertaking, it is not considered by the Committee possible for the British Association, either alone or acting in concert with the special scientific societies, to undertake the translation of entire papers from foreign journals.'

It was mentioned in the course of the discussion that no complete set of abstracts of papers in physics is published in English; and the advantage of such abstracts being generally recognised, Professor Reinold undertook, at the request of the Committee, to bring the subject before the Council of the Physical Society of London and report the result to the Committee.

Professor Reinold reports as follows:—

'The Council of the Physical Society have decided that they are not at present in a position to undertake so vast a work as the publication of abstracts of foreign physical papers or even to assist in any adequate manner in such an undertaking. It has been decided, however, to publish from time to time translations *in extenso* of important papers appearing in foreign journals.'

The Committee have found it unnecessary to expend any portion of its grant.

Report of a Committee, consisting of Professors McLeod *and* Ramsay *and* Messrs. J. T. Cundall *and* W. A. Shenstone (*Secretary*), *appointed to further investigate the Action of the Silent Discharge of Electricity on Oxygen and other Gases.*

The work of this Committee has been actively continued during the past year. An apparatus has been constructed for the preparation and storage of gases in a pure state. This apparatus has been put together entirely before the blowpipe, and has no taps nor joints except such as are protected by mercury, and therefore affords the best guarantee of the purity of the gas prepared and stored within it at present attainable. The constructing of this apparatus has occupied a considerable period, and has prevented the execution of so much of the work that it is proposed to carry out as would otherwise have been possible; nevertheless considerable progress has been made in several directions. Oxygen has been prepared which, from the mode of preparation, may be presumed to contain not more than one part of nitrogen in two hundred million parts of the gas; and, though it is not possible to obtain reagents of a similar degree of purity, by acting on the gas with specially purified phosphorus it has been established by experiment that the gas is undoubtedly in a very pure state.

Very pure oxygen has been enclosed with phosphorus pentoxide in sealed tubes for periods of many weeks and subsequently submitted to the action of the silent discharge of electricity. The results of repeated experiments show that such oxygen is freely convertible into ozone. Whether pure and dry oxygen is more capable of ozonification than oxygen in a less pure state has, however, still to be decided by repetitions of the experiments with various forms of apparatus. But the variable efficiency of ozone-generators under apparently identical conditions has to be overcome before the results of quantitative experiments can be compared one with another; therefore the Committee are at present

unable to report more fully on this point and on the main object of their work, viz., the influence of heat, pressure, &c., on the formation of ozone. Further progress has been made in the examination of the character of the silent discharge of electricity, and in the study of the actions of ozone and mercury on each other. It has been ascertained that ozone, pure and dry, except for the presence of oxygen, affects the surface-tension of mercury in the well-known manner, and is itself presently reconverted into oxygen. This change, however, is *not* accompanied by oxidation of the mercury, such as occurs even when only a trace of moisture is present.

The experiments on the chemical action of ozone on mercury and other substances are being continued, and, though their progress must be slow, considerable advance may be hoped for during the coming year. The other work undertaken by the Committee is also being actively continued, and it is proposed that the Committee shall be reappointed.

NOTE.—No experimental details are introduced into this report, as a full description of the work done has already been published in a paper printed in the 'Journal of the Chemical Society' for July 1887.

Report of the Committee, consisting of Professors TILDEN *and* W. CHANDLER ROBERTS-AUSTEN *and* Mr. T. TURNER (*Secretary*), *appointed for the purpose of investigating the Influence of Silicon on the Properties of Steel.* (*Drawn up by* Mr. T. TURNER.)

WHEN the above Committee were appointed at the last meeting of the Association a series of experiments had already been commenced, and a preliminary notice of these appeared in the Report for last year. This series of experiments has been completed, and full details have been published ('Jour. Chem. Soc.' 1887, p. 129). A second set of observations in continuation of the work has also been commenced, and the results are so far advanced that it is hoped to publish details in a few months.

In the paper in the 'Journal of the Chemical Society' a short account is given of the results hitherto obtained by other observers, and it is believed that the present state of our knowledge may be summarised as follows:—

1. Ingot iron. Silicon promotes soundness; it resembles carbon in increasing the tenacity and hardness; it should not exceed 0·15 per cent. if the metal has to be rolled; and in some cases it produces brittleness when cold.

2. In steel castings. Silicon promotes soundness; it is, however, regarded as a necessary evil, and excess should be avoided as tending to brittleness and low extension; about 0·3 per cent. is generally recommended.

3. In crucible steel. A few hundredths per cent. is necessary to produce soundness; it is generally agreed that considerable quantities of silicon may be present without injury to the material.

4. Manganese appears to be capable of neutralising the ill effect due to silicon.

The first series of experiments was undertaken to determine the effect of silicon on the properties of specially pure iron. For this purpose

TABLE A.—*Genera*

No.	Chemical analysi (By Mr. J. P. Walton)					Hot tests	Cold tests	Welding tests	Specific extension		Modulus of elasticity	
	C.	Si.	S.	Mn.	P.				ε_t	ε_c	E	E
1	0·02	·0098	0·039	0·06	0·04	Worked well at welding heat; red short at dull red heat.	Good	Perfect weld	0·317	0·314	31,590,000	31,870,000
	—	—	—	—	—	—	—	—	—	—	—	—
2	0·029	0·02	0·03	0·10	0·03	Do.	Do.	Broke owing to red shortness	0·326	0·329	30,640,000	30,420,000
	—	—	—	—	—	—	—	—	—	—	—	—
3	0·02	0·027	0·028	0·07	0·042	Do.	Do.	Very good weld	0·321	0·321	31,120,000	31,120,000
	—	—	—	—	—	—	—	—	—	—	—	—
4	0·076	0·035	0·03	0·10	0·06	Do.	Do.	Do.	0·328	0·320	30,530,000	31,250,000
	—	—	—	—	—	—	—	—	—	—	—	—
5	0·057	0·039	0·03	0·09	0·05	Do.	Do.	Do.	0·330	0·321	30,300,000	31,120,000
	—	—	—	—	—	—	—	—	—	—	—	—
6	0·052	0·08	0·036	0·09	0·06	Do.	Do.	Do.	0·311	0·323	32,130,000	31,000,000
	—	—	—	—	—	—	—	—	—	—	—	—
7	0·113	0·117	0·015	0·08	0·045	Do.	Do.	Do.	0·333	0·326	30,070,000	30,640,000
	—	—	—	—	—	—	—	—	—	—	—	—
8	0·034	0·113	0·033	0·09	0·08	Do.	Do.	Not so good	0·312	0·313	32,100,000	32,000,000
	—	—	—	—	—	—	—	—	—	—	—	—

mary of Results.

t of elasticity per sq. in.		Breaking load per sq. in.		Ratio of limit to break	Extension per cent. on 10 in.	Reduction of area per cent.	Relative hardness	Remarks
ds	Tons	Pounds	Tons					
00	12·77	48,850	21·80	0·586	24·7	76·3	18	Silky.
80	13·25	48,810	21·79	0·608	30·7	77·8	—	Very finely silky.
00	13·39	46,410	20·72	0·646	19·5	43·4	16	Fracture irregular; about 60 per cent. silky; the remainder in patches and pipes of crystal.
10	12·77	42,940	19·17	0·666	15·7	37·3	—	Very unsound and faulty; irregular crystalline spots; surface extremely distressed all over.
30	16·30	49,040	21·89	0·744	24·2	63·7	15	Fracture silky, but full of pipes and reedy holes in part filled with crystalline siliceous matter; some small specks of crystal.
30	19·19	48,410	21·61	0·888	27·8	71·1	—	Very finely silky, but with three large and about 20 small round pipes, filled with siliceous matter, which flew out in a cloud of dust on fracture; surface reedy.
50	15·11	51,920	23·18	0·652	15·6	30·0	17	Fracture irregular, with unsound pipes or fissures; mostly crystalline granular; edges silky.
70	16·28	51,430	22·96	0·709	17·1	33·7	—	Like No. 6, but more irregular, and surface a good deal distressed.
90	15·22	50,640	22·60	0·673	15·4	36·3	17	Fracture irregular and not entirely sound; about 30 per cent. finely crystalline, rest silky.
90	17·63	53,670	23·97	0·735	21·1	39·1	—	Irregular; mostly silky, but with crystalline spots; in places unsound and reedy; surface reedy.
50	17·92	54,280	24·23	0·739	24·0	46·0	20	Silky, but with irregular crystalline specks and pipes.
30	15·53	52,050	23·24	0·668	24·5	43·8	—	Silky but irregular, with crystalline spots and pipes; surface a little distressed.
30	17·73	61,490	27·45	0·646	12·8	19·7	21	Fracture 65 per cent. finely crystalline, the rest half finely granular; half silky; surface very much distressed on one side.
20	18·27	64,180	28·65	0·638	18·4	33·9	—	Fracture about 65 per cent. finely crystalline, the rest irregular, for the most part silky; surface a good deal distressed.
20	18·58	57,720	25·77	0·721	22·0	47·7	20	Silky; specked with crystals and silica (yellowish crystalline material), a little reedy on surface.
0	18·17	57,330	25·59	0·710	17·7	36·2	—	Somewhat irregular, silky—with flattened pipes containing crystalline siliceous matter; surface a little distressed.

molten iron was taken from the Bessemer converter at the end of the 'blow' and before any addition of ferromanganese had been made. This was mixed in a crucible with various proportions of melted cast iron containing about 10 per cent. of silicon, and the product was afterwards examined. The composition of these materials was as follows :—

	C.	Si.	S.	Mn.	P.
Bessemer Iron . .	0·02	0·0098	0·039	0·06	0·04
Silicon Pig . . .	1·96	10·30	0·02	1·90	0·17

In Table A is given a general summary of the results obtained. The mechanical tests were conducted by Professor A. B. W. Kennedy, and duplicate experiments gave concordant results. The mean values deduced from these experiments are given in Table B. The letter D is used to indicate that in these cases it is doubtful if thorough mixture was obtained. Other ingots were prepared containing more silicon, but as these could not be rolled no mechanical tests were performed.

TABLE B.—*Mean Results of Tensile Tests.* Professor KENNEDY.

No.	Si. p. c. found	Limit of elasticity. Tons per sq. in.	Breaking load. Tons per sq. in.	Ratio limit to break	Extension per cent. on 10 inches	Reduction of area per cent.	Relative hardness
1	0·0098	13·01	21·80	0·597	27·7	77·0	18
2	0·02	13·08	19·95	0·656	17·6	40·3	16
D 3	0·027	17·75	21·75	0·861	26·0	67·4	15
4	0·035	15·69	23·07	0·680	16·3	31·8	17
5	0·039	16·42	23·28	0·704	18·2	37·7	17
6	0·08	16·72	23·77	0·704	24·2	44·9	20
7	0·117	18·00	28·05	0·642	15·6	26·8	21
D 8	0·13	18·37	25·68	0·715	18·8	41·9	20

The relative hardness was determined, as in my experiments on cast iron, by means of the weight in grams necessary to produce a scratch with a diamond on drawing its point over the smooth surface of the metal. The following list will illustrate the values obtained on applying such a method of examination to various substances. On comparing the values given in Table B it will be seen that the relative hardness was not very greatly influenced by the proportion of silicon added.

Substances.	Relative hardness.
Steatite	1
Lead (commercial)	1
Tin ,,	2·5
Rock salt	4
Zinc (pure annealed)	6
Copper (pure annealed)	8
Calcite	12
Softest iron	15
Fluor-spar	19
Mild steel	21
Tyre steel	20–24
Good cast iron	21–24
Bar iron	24

Substances.	Relative hardness.
Apatite	34
Hard cast-iron scrap	36
Window glass	60
Good razor steel	60
Very hard white iron	72

The following are the general conclusions arrived at from this series of experiments. On adding silicon, in the form of silicon pig, to the purest Bessemer iron, the following results are obtained:—

The metal is quiet in the mould when even a few hundredths per cent. of silicon are added. The metal is originally red short, especially at a dull red heat, though it works well at a welding temperature; the red shortness is increased by silicon. In all cases examined, the metal was tough cold, and welded well, silicon having little or no influence. Silicon increases the elastic limit and tensile strength, but diminishes the elongation and the contraction of area, a few hundredths per cent. having a remarkable influence in this respect. The appearance on fracture by tensile force is changed from finely silky to crystalline, while the fracture produced by a blow gradually becomes more like that of tool steel as silicon increases. The hardness increases with the increase of silicon, but appears to be closely connected with the tenacity. With 0·4 per cent. of silicon and 0·2 per cent. of carbon, a steel was obtained difficult to work at high temperatures, but tough when cold, capable of being hardened in water, and giving a cutting edge which successfully resisted considerable hard usage. In some cases silicon was present in the oxidised condition; the effect is then very different, and the mechanical properties of the metal more nearly resemble those of the original Bessemer iron.

In the second series of experiments various proportions of silicon have been added to ingot metal, containing manganese and carbon, as ordinarily met with in commerce. The results are not yet quite ready for publication, but they show that manganese greatly modifies the effect of silicon in producing red shortness, and hence enables the metal to be readily rolled and otherwise worked, even in presence of several tenths per cent. of silicon. The low extension, however, though not nearly so marked as before, is still observed, despite the presence of manganese; and hence, for the majority of the applications of mild steel, silicon does not appear to be advantageous.

Third Report of the Committee, consisting of Professor G. FORBES (*Secretary*), Captain ABNEY, Dr. J. HOPKINSON, Professor W. G. ADAMS, Professor G. C. FOSTER, Lord RAYLEIGH, Mr. PREECE, Professor SCHUSTER, Professor DEWAR, Mr. A. VERNON HARCOURT, Professor AYRTON, Sir JAMES DOUGLASS, *and* Mr. H. B. DIXON, *appointed for the purpose of reporting on Standards of Light.*

THE Committee have been anxious during the past year to carry out comparative experiments on the various standards of light hitherto proposed, but have been prevented by want of funds from doing much. Professor W. G. Adams, however, has presented a report to the Committee on pre-

liminary experiments made by him, and the Committee are fully convinced that, if provided with funds, they will be able during the next year to complete experiments which will lead to recommendations, which, if adopted, will place the question of authorised standards on a satisfactory footing.

Third Report of the Committee, consisting of Professors RAMSAY, TILDEN, MARSHALL, *and* W. L. GOODWIN (*Secretary*), *appointed for the purpose of investigating certain Physical Constants of Solution, especially the Expansion of Saline Solutions.*

THE experiments on invaporation described in our last report have been continued, and new series have been begun. The process of invaporation is so slow that our report each year must necessarily be imperfect in many points. Of all the experiments set up (and some of these have been going on for nearly two years) only four are completed. The method formerly employed, of sealing in glass tubes and opening by breaking the tubes, was found inconvenient, several interesting experiments having been spoiled by various accidents in sealing and opening. We next tried the so-called 'Gem' and 'Crown' jars, used a great deal in America for sealing up fruits, &c. They are closed by means of a glass cap, the rim of which is pressed down upon a flange on the neck of the bottle by means of a metallic screw-ring working upon a thread below the flange. A ring of caoutchouc lies upon the flange and is pressed upon by the rim of the cap. Out of a dozen carefully selected specimens of these jars only two were found to be even approximately tight when tested by the invaporation process. For example, experiment 6·2 shows a loss of 1·2661 gram of water in 133 days. Still, the jars answer their original purpose, and can be closed tightly enough to prevent the entrance of putrefactive and fermentative germs. The rate of invaporation was found to be very much slower when the jars were used, although larger tubes were employed, and thus larger invaporating surfaces secured. A comparison of A.2 and C.2 brings out this difference in rates. In A.2 half the quantity of sodium chloride invaporates in 111 days six times as much water as is invaporated by the sodium chloride of C.2 in 133 days. Of course, this is to be explained, in part at least, by the lower vapour tension due to the escape of moisture from the imperfectly closed jar. But, that there is another cause seems to follow from the case of C.3. The jar in this case was almost air-tight, allowing the escape of only 0·2592 gram of water in 131 days. The total water invaporated during this period was 0·8689 gram, as compared with 1·435 gram invaporated in 56 days by smaller quantities of salts inclosed in a sealed tube (see A.1). The jars were very much larger than the sealed tubes, and doubtless this circumstance retarded invaporation when the jars were used. The jars were rejected in favour of wide-mouthed stoppered bottles, the stoppers of which were greased with lard. The loss of water from these bottles was found to be scarcely appreciable.

In the following tables Ma = mass in grains, Mo = relative numbers of molecules, P = period of invaporation in days, reckoning from the beginning of the experiment, Q = masses of water in the small tubes, R = relative numbers of molecules of water in the small tubes.

Series A, Experiment 1; *begun February* 11, 1886.

Substances	Ma	P		P	Q	P	Q	P	Q	P	Q	P	Q
Sodium chloride . .	1·1672	56	0·8058	159	1·1978	172	1·2392	314	1·4207	460	1·4183	534	1·4155
Potassium chloride .	1·4882	April 8	0·6292	July 20	0·2332	Aug. 2	0·1900	Dec. 22	0·0076	May 17,	0·0076	July 30	0·0090
Water	1·4400	—	0·0000	—	0 0000	—	0·0000	—	0·0000	1887	0·0000	—	0·0000
	—	—	1·4350	—	1·4310	—	1·4292	—	1·4283	—	1·4259	—	1·4245
	Mo	—	R	—	R	—	R	—	R	—	R	—	R
NaCl	25	—	55·96	—	83 18	—	86·06	—	98·66	—	98·49	—	98·29
KCl	25	—	43·69	—	16·19	—	13·19	—	0·54	—	0·54	—	0·63
H_2O	100	—	0·00	—		—		—		—		—	
	—	—	99 65	—	99·37	—	99·25	—	99·20	—	99·03	—	98·92

A, 2; *begun October* 30, 1885.

Substances	Ma	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q
Sodium chloride . .	0·5836	111	0·9516	151	1·1160	262	1·3331	276	1·3386	417	1·3523	638	1·3601
Potassium chloride	0·7441	Feb. 18,	0 4866	Mar. 30	0·3166	July 19	0·0991	Aug. 2	0·0976	Dec. 21	0·0841	July 30	0·0723
Water	1·4400	1886	0·0000	—		—		—		—		1887	
	—	—	1·4382	—	1·4326	—	1·4322	—	1·4362	—	1·4364	—	1·4324
	Mo	—	—	—	—	—	R	—	R	—	R	—	R
NaCl	12·5	—	—	—	—	—	92·58	—	92·96	—	93·91	—	94·45
KCl	12·5	—	—	—	—	—	6·88	—	6·78	—	5·84	—	5·02
H_2O	100	—	—	—	—	—	0·00	—		—		—	
	—	—	—	—	—	—	99·46	—	99·74	—	99·75	—	99·47

A, 3; *begun August* 5, 1886.

Substances	Ma	P	Q	P	Q								
Sodium chloride .	0·2918	286	1·1772	359	1·1898								
Potassium chloride .	0·3721	May 18,	0·2515	July 30	0·2367								
Water . . .	1·4400	1887	0·0000	—									
	—	—	1·4287	—	1·4265								
	Mo	—	R	—	R								
NaCl	6·25	—	81·75	—	82·63								
KCl	6·25	—	17·47	—	16·44								
H_2O	100	—	0·00	—									
	—	—	99·22	—	99·07								

A, 4; *begun November* 13, 1885.

Substances	Ma	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q
Sodium chloride . .	0·1459	111	0·6788	143	0·7020	249	0·7493	404	0·7652	550	0·7788	624	0·7769
Potassium chloride .	0·1860	Mar. 4,	0·7710	April 5	0·7370	July 20	0·6831	Dec. 22	0·6595	May 17,	0·6274	July 30	0·6236
Water	1·4400	1886	0·0000	—		—		—		1887		—	
	—	—	1·4498	—	1·4390	—	1·4324	—	1·4247	—	1·4062	—	1·4005
	Mo	—	—	—	—	—	—	—	R	—	R	—	R
NaCl	3·125	—	—	—	—	—	—	—	53·14	—	54·09	—	53·95
KCl	3·125	—	—	—	—	—	—	—	45·79	—	43·54	—	43·31
H_2O	100	—	—	—	—	—	—	—	0·00	—		—	
	—	—	—	—	—	—	—	—	98·93	—	97·63	—	97·26

Substances	Ma	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q
Sodium chloride .	0·1459	281	0·8977	354	1·0130								
Potassium chloride .	0·1860	May 18,	0·6495	July 30	0·8220								
Water . . .	2·8800	1887	1·3309	—	1·0371								
	—	—	2·8781	—	2·8721								
Series B, Experiment 1 ; *begun March* 11, 1886.													
Sodium chloride . .	0·5836	36	1·1271	131	1·4300	144	1·4294	286	1·4304	432	1·4281	506	1·4264
Potassium chloride .	0·3721	April 16	0·3129	July 20	0·0053	Aug. 2	0·0059	Dec. 22	0·0053	May 17,	0·0051	July 30	0·0067
Water	1·4400	—	0·0000	—		—		—		1887		—	
	—	—	1·4400	—	1·4353	—	1·4353	—	1·4357	—	1·4332	—	1·4331
	Mo	—	R	—	R	—	R	—	R	—	R	—	R
NaCl	12·5	—	78·27	—	99·31	—	99·26	—	99·33	—	99·18	—	99·06
KCl	6·25	—	21·73	—	0·37	—	0 41	—	0·37	—	0·35	—	0·46
H_2O	100	—	0·00	—		—		—		—		—	
	—	—	100·00	—	99·68	—	99·67	—	99·70	—	99·53	—	99·52
Series D, Experiment 1.													
	Ma	P	Q	P	Q								
Sodium chloride .	1·1672	24	0·0034	56	0·0024								
Lithium chloride .	0·8474	—	1·1506	—	1·1551								
Water . . .	1·4400	—	0·0000	—	—								
	—	—	1·1540	—	1·1575								
	Mo	—	R	—	R								
NaCl	25	—	0·24	—	0·17								
LiCl	25	—	79·90	—	80·22								
H_2O	100	—	0·00	—	—								
	—	—	80·14	—	80·39								

D, 2 ; *begun January* 30, 1886.

Substances	Ma	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q
Sodium chloride .	0·5836	42	0·0031	77	0·0019	171	0·0005	326	0·0004	472	0·0006*	546	0·1386
Lithium chloride .	0·4237	March 13	1·4459	April 17	1·4466	July 20	1·4443	Dec. 22	1·4463	May 17, 1887	1·4434	July 30	1·9107
Water . . .	1·4400	—	0·0000	—	—	—	—	—	—		—	—	0·0950
	—	—	1·4490	—	1·4485	—	1·4448	—	1·4467	—	1·4440	—	2·1443
	Mo	—	—	—	—	—	—	—	R	—	R	—	—
NaCl	12·5	—	—	—	—	—	—	—	0·0	—	0·0	—	—
LiCl	12·5	—	—	—	—	—	—	—	100·0	—	100·0	—	—
H_2O	100	—	—	—	—	—	—	—	—	—	—	—	—

D, 3 ; *begun January* 23, 1886.

Substances	Ma	P	Q	P	Q	P	Q	P	Q	P	Q
Sodium chloride .	0·5136	62	0·4562	177	0·6219	191	0·6365	333	0·7196	476	0·7492
Lithium chloride .	0·4237	March 26	2·4154	July 19	2·2434	Aug. 2	2·2284	Dec. 22	2·1459	May 14, 1887	2·1083
Water . . .	2·8800	—	0·0000	—	—	—	—	—	—		—
	—	—	2·8716	—	2·8653	—	2·8649	—	2·8655	—	2·8575
	Mo	—	—	—	—	—	—	—	R	—	R
NaCl	6·25	—	—	—	—	—	—	—	24·99	—	26·02
LiCl	6·25	—	—	—	—	—	—	—	74·48	—	73·20
H_2O	100	—	—	—	—	—	—	—	0·00	—	—
	—	—	—	—	—	—	—	—	99·47	—	99·22

* At this stage, 0·7015 grain additional water was inserted into the water tube.

D, 4; *begun August* 28, 1886.

Substances	Ma	—	P	Q	—	P	Q	P	Q
Sodium chloride .	0·2918	During the first period in a gem jar	125 Dec. 31	0·1125	Now put into a stoppered bottle, the stopper being well greased	287 June 11, 1887	0·5681	336 July 30	0·8111
Lithium chloride .	0·2119			0·9413			1·2284		1·2997
Water . . .	2·8800		—	1·6746			0·9247	—	0·6084
	—	—	—	2·7284		—	2·7212	—	2·7192
	Mo	—	—	R	—	—	R	—	R
NaCl	3·125	—	—	3·91	—	—	19·73	—	28·16
LiCl	3·125	—	—	32·69	—	—	46·65	—	45·13
H_2O	100	—	—	58·75	—	—	32·11	—	21·13
	—	—	—	94·75	—	—	94·49	—	94·42

Check Experiment 1; *begun August* 25, 1886.

Substances	Ma	—	P	Q	—	P	Q	P	Q
Sodium chloride (tube 67)	1·1672	During the first period in a gem jar	128 Dec. 31.	0·3729	Now put into a stoppered bottle, the stopper being well greased	290 June 11, 1887	0·9260	342 Aug. 1	1·2116
Sodium chloride (tube 68)	1·1672		—	0·4139			0·9403	—	1·2150
Water (tube 69) . .	5·7600	—	—	4·4385		—	3·3513	—	2·7843
	—	—	—	5·2253	—	—	5·2176	—	5 2109

A.1 is evidently completed. The condition at the end of 314 days is practically the same as that at the end of 460 days. The potassium chloride retains only a few milligrams of water. At the end of 534 days the potassium chloride has gained 1·4 milligram, while the sodium chloride has lost 2·8 milligrams. These numbers represent the change between the 260th and the 534th day. The quantities are so small that they may be due to unavoidable errors of experiment. It is to be noted, however, that the period is a hot one, including as it does the month of July, during which the average daily minimum was 66° F., and the average daily maximum 78° F. Other observations made in the course of these experiments have led us to believe that the distribution of the water is appreciably affected by the temperature. It has been shown by Wüllner (Jahresber., 1860, 47–49), that the effect of salts in solution in decreasing vapour tension is increased by rise of temperature. From this it follows that invaporation is more powerful at high than at low temperatures, and we would expect this effect to be different for different salts.

A.2 is still in progress, but invaporation from the potassium chloride to the sodium chloride is proceeding so slowly (a little over one centigram during the last 221 days!) that the limit must be nearly reached.

A.3 is not yet completed. Water is still passing from the potassium chloride to the sodium chloride.

A.4 is almost, if not quite, in equilibrium, and it is to be observed that the ratio in which the water is divided does not depart far from unity.

A.5, in progress for a year, shows that after sufficient dilution, potassium chloride invaporates more rapidly than sodium chloride.

Series B includes the experiments made to show the effect of increasing the relative proportion of sodium chloride. A comparison of B.1 with A.2 shows that increasing the relative proportion of sodium chloride causes more rapid invaporation, and, when the quantity of water is small, more complete desiccation of the potassium chloride. The quantity of water remaining with the potassium chloride after the 131st day is fairly constant, and it is to be observed that the maxima come immediately after the hot months (*vide supra*).

Series D includes experiments V., VI., and VII., of our previous report (see D.1, D.2, and D.3). A study of D.4 shows that, after a certain degree of diluteness is attained, sodium chloride invaporates more rapidly than lithium chloride, and it seems probable that, given enough water, sodium chloride would invaporate as much as, if not more than, lithium chloride.

A check experiment was made by using two equal weights of sodium chloride placed in tubes of nearly the same diameter, and allowing them to invaporate water. If the conditions were the same in the two tubes, and did not vary from part to part of the enclosed space, invaporation would go on at the same rate in the tubes. The small differences observed are easily explained. In tube No. 68 a small quantity of the salt remained as fine powder on the sides of the tube. This, deliquescing rapidly, exposed a large invaporating surface, and thus during the first period No. 68 gained water more rapidly than No. 67. This advantage disappeared as soon as the solution adhering to the walls became very dilute. Then, during the second period, No. 67 invaporated more rapidly than No. 68. This was owing to the fact that the diameter of

No. 67 was slightly greater than that of No. 68, so that the solution in No. 67 exposed a larger invaporating surface. This second cause of variation is not so great as the first.

An interesting comparison could be made between the results of invaporation experiments and the vapour tensions of the corresponding saline solutions; but it will be necessary to await the completion of a sufficient number of experiments to permit the plotting of curves, in order that the comparison may be advantageously made.

Report of the Committee, consisting of Professor TILDEN, Professor RAMSAY, *and* Dr. W. W. J. NICOL (*Secretary*), *appointed for the purpose of Investigating the Nature of Solution.*

Supersaturation of Salt Solutions.[1]—The various physical constants of supersaturated and non-saturated solutions were examined in two ways. (1) Starting with a non-saturated solution of a salt at a high temperature it was allowed to cool and thus to become more and more concentrated till it reached its saturation point, while on further fall of temperature it became supersaturated; (2) solutions of the salt were prepared of definite strengths, extending equal distances on either side of the saturation point, and their physical properties were examined at a definite temperature (20° C.). The salts examined were the following:—

Sodium sulphate, sodium phosphate, sodium thiosulphate, sodium carbonate, zinc sulphate, magnesium sulphate.

The physical constants examined were—

Rate of expansion, specific viscosity, molecular volume, and electrical conductivity.

In no case did the curves representing the change in the value of the physical constants with temperature or concentration exhibit the slightest change in direction above or below the saturation point.

These experiments show that there is no marked change in the physical properties of a solution when it becomes supersaturated either through fall of temperature or by the addition of salt. Non-saturated, saturated, and supersaturated solutions have therefore the same constitution; they differ only in degree, not in kind.

Specific Viscosity of Salt Solutions.—The experiments in this direction are incomplete, but new forms of apparatus have been devised which have yielded highly satisfactory results.

Preliminary experiments have been made with NaCl, KCl, $NaNO_3$, and KNO_3 in different strengths of solution, the general result being to cast doubts on some of the results obtained by Hannay as to the proportionality of the retardation of flow and the amount of salt present.

The forms of the curves for the sodium salts are essentially the same, but differ completely from those for the corresponding potassium salts, the latter having a minimum time of flow at a strength of 2 to 3 molecules of salt per 100 water molecules and approximately the same rate as pure water when $n=5$ for KNO_3 and KCl.

A large number of further experiments will be required before the

[1] *Journ. Chem. Soc.* 1887, p. 389.

work is sufficiently advanced to justify the drawing of general conclusions from it.

Change of volume on the precipitation of barium sulphate by various sulphates.

Two series of experiments have been completed, one with solutions containing one equivalent of the salts in 50 molecules of water, the other with solutions of half this strength. The results are as follows:—VC. is the change of volume in cubic centimetres resulting on the mixture of the solution of barium chloride containing 1 gram equivalent with excess of the precipitant.

$BaCl_2xH_2O$ + Excess.		MSO_4xH_2O.	
M. $x=100$	VC.	M. $x=200$	VC.
Li_2	—	Li_2	43·6
Na_2	40·7	Na_2	43·5
K_2	40·7	K_2	43·9
Cd	37·3	Cd	40·4
Mg	36·2	Mg	39·1
Zn	35·7	Zn	38·6
Co	34·7	Co	38·3
Cu	34·8	Cu	38·1
Ni	34·5	Ni	37·8
Fe	35·0	Fe	—
Mn	35·0	Mn	—

the mean difference between corresponding members of the two series being 3·1, due to the different dilutions.

It is to be noted that the first three metals yield closely agreeing results, and are marked off by a gap of 3·4—3·5 from the others, while these are all comprised within 2·8—2·6. It is probable that this different behaviour of the magnesian sulphates is due to the presence of water of constitution, cadmium forming a connecting link between this group and that of the alkali metals.

Vapour Pressure of Salt Solutions.—The work done has been confirmed to a great extent by Emden (Wied. 'Ann.' 1887, xxxi. 145), who employed the barometric method of experiment. He, however, maintains the truth of von Babo's law, that the vapour pressure of a solution at different temperatures always bears the same proportion to that of pure water, or $p = \lambda P$; where p = pressure from salt solution, P = from pure water, and λ = a constant. This point is a most important one, for unless λ varies with the temperature, there would be no reason why a salt should change in solubility with rise of temperature, or at any rate why the solubility of all salts should not vary equally with change of temperature.

In order to settle this question new apparatus has been devised whereby water and salt solution can be compared under precisely similar conditions, and it is proposed to extend the observations from ordinary temperatures up to 100° C., advantage being taken of Professors Ramsay's and Young's methods of maintaining constant temperatures by means of the vapour of liquids boiling under definite pressures.

Report of the Committee, consisting of Professors TILDEN, MCLEOD, PICKERING, *and* RAMSAY, and Drs. YOUNG, A. R. LEEDS, *and* NICOL (*Secretary*), *appointed for the purpose of reporting on the Bibliography of Solution.*

A CIRCULAR was issued to the members of the Committee, enclosing a proposed classification and list of journals, and asking for suggestions as to alterations, additions, &c. As a result of the answers to this circular, the following classification was adopted :—

CLASSIFICATION.

CLASS A.—*Theoretical.*

Section 1. Without original experimental work.
„ 2. With original experimental work.

„ B.—*Determination of Solubilities.*

Section 1. Solids
„ 2. Liquids } in liquids.
„ 3. Gases

„ C.—*Physical Properties of Solutions.*

Section 1. Densities and molecular volumes.
„ 2. Dilatation.
„ 3. Freezing-points.
„ 4. Vapour pressures and boiling-points.
„ 5. Capillarity.
„ 6. Diffusion.
„ 7. Refraction and dispersion.
„ 8. Rotatory power.
„ 9. Magnetic rotatory power.
„ 10. Absorption spectra.

„ D.—*Thermo-chemical Data.*

Section 1. Specific heat.
„ 2. Heat of solution, precipitation, &c.

NOTE.—Papers not coming under any of the above will be included under Miscellaneous.

The list of journals is as follows :—

LIST OF JOURNALS.

To be referred to by number in classifying slips.

1. 'American Journal of Science and Arts.'
2. 'Memoirs of the American Academy of Arts and Sciences.'
3. Proceedings of the above.
4. 'Annals of Philosophy.'
5. 'Philosophical Magazine.'
6. The 'Edinburgh Journal of Science' (Brewster).
7. Nicholson's 'Journal of Natural Philosophy.'
8. The 'Chemical Gazette.'
9. The 'Chemical News.'
10. The 'Laboratory.'
11. 'Nature.'
12. The 'Pharmaceutical Journal.'
13. 'Journal of the Society of Chemical Industry.'
14. 'Philosophical Transactions,' R.S.L.

LIST OF JOURNALS—(*continued*).

15. Proceedings of the above.
16. 'Philosophical Transactions,' R.S.E.
17. Proceedings of the above.
18. 'Memoirs of the Royal Irish Academy.'
19. 'Journal of the Chemical Society of London.'
20. Liebig's 'Annalen.'
21. Gilbert's, Poggendorff's, and Wiedemann's 'Annalen.'
22. Schweigger's 'Journal.'
23. Kolbe's 'Journal für Practische Chemie.'
24. Fresenius' 'Zeitschrift.'
25. Carl's 'Repertorium.'
26. 'Chemisches Centralblatt.'
27. 'Sitzung berichte d. k. Acad. der Wissen. Wien.'
28. 'Berichte d. Deut. Chem. Gesellschaft. Berlin.'
29. 'Annales de Chimie et de Physique.'
30. 'Bulletin de Pharmacie.'
31. 'Journal de Pharmacie.'
32. 'Comptes Rendus.'
33. 'Bulletin de la Société Chimique de Paris.'
34. 'Gazetta Chimica Italiana.'

The following members of the Committee undertook to look over the following journals:—

Professor TILDEN.—'Annales de Chimie et de Physique,' the 'Pharmaceutical Journal.'

Professor MCLEOD.—'Proceedings of the Royal Society.'

Professor PICKERING.—'Transactions of the Royal Societies of London and Edinburgh,' 'Proceedings of the Royal Society, Edinburgh.'

Professor RAMSAY.—'Journal of the Chemical Society,' 'Comptes Rendus.'

Dr. YOUNG.—Liebig's 'Annalen.'

Dr. NICOL.—'Annals of Philosophy,' 'Philosophical Magazine,' the 'Edinburgh Journal of Science,' Nicholson's 'Journal of Natural Philosophy,' 'Journal of the Society of Chemical Industry,' Gilbert's, Poggendorff's, and Wiedemann's 'Annalen,' Schweigger's 'Journal,' Carl's 'Repertorium.'

The classification and list of journals was issued to the members who had undertaken work along with the classification slips.

DIRECTIONS FOR FILLING UP THE CLASSIFYING SLIPS.

The titles of papers are to be given in full in the original language.

Other references will, as a rule, be left blank, but may be used for the original reference when the paper is a translation.

Papers on electrical constants of solutions, unless they come under Class A, are to be passed over.

Papers containing experimental work, unless *professedly* theoretical, will come in classes B, C, and D.

The volume number is to be given in ordinary, not Roman figures.

The periodical is to be referred to by its number in the accompanying list.

With the following circular enclosed:—

BIRMINGHAM, *March* 21, 1887.

B. A. COMMITTEE.—*Bibliography of Solution.*

DEAR SIR,—I have sent you by this post a number of classifying slips, and enclose a revised list of journals and classification. I wish also to

draw your attention to the directions to be followed in filling up the slips which you will find on the other side of this.

If you will kindly send me the slips in small batches as they are filled up it will greatly facilitate the work of filling in the other references.

Yours truly,

W. W. J. Nicol, *Secretary.*

The result of the work up to the present has been that the whole of the following journals have been searched:—

'Annals of Philosophy.'
'Edinburgh Journal of Science.'
('Brewster,' 'Jameson,' and the 'New Edinburgh Philosophical Journal.')
Nicholson's 'Journal.'
Schweigger's 'Journal.'
Gilbert's 'Annalen,' Wiedemann's 'Annalen.'
Carl's 'Repertorium.'

In all 369 volumes.

Portions of the following have been searched:—

'Philosophical Magazine.'
Poggendorff's 'Annalen.'
Liebig's 'Annalen.'
'Transactions and Proceedings of the Royal Society, Edinburgh.'

In all 219 volumes.

These 588 volumes contained the following papers:-

A. 1=11; 2=12	23
B. 1=80; 2=2; 3=31	113
C. 1=38; 2=10; 3=5; 4=19; 5=5; 6=26; 7=5; 8=9; 9=1; 10=2	120
D. 1=14; 2=16	30
Miscellaneous	69
Total	355

The Committee would recommend as members of the Committee other gentleman who have access to the journals on the list, and who would be willing to take an active share in the work.

Report of the Committee, consisting of Professor Ray Lankester, Mr. P. L. Sclater, Professor M. Foster, Mr. A. Sedgwick, Professor A. M. Marshall, Professor A. C. Haddon, Professor Moseley, *and* Mr. Percy Sladen (*Secretary*), *appointed for the purpose of making arrangements for assisting the Marine Biological Association Laboratory at Plymouth.*

Your Committee have pleasure in stating that the building for the Laboratory of the Marine Biological Association at Plymouth is approaching completion.

Your Committee report that they have paid to the Marine Biological

Association the sum of 50*l.*, placed at their disposal for that purpose; and they hope that the Council will continue their support to this national undertaking, and that the grant may be not only renewed but increased for the ensuing year.

Fifth Report of the Committee, consisting of Mr. R. ETHERIDGE, Dr. H. WOODWARD, *and* Professor T. RUPERT JONES (*Secretary*), *on the Fossil Phyllopoda of the Palæozoic Rocks*, 1887.

§ I. CERATIOCARIS TYRANNUS and C. PATULA.—Continuing our researches on the *Ceratiocarides*, especially with a view to a monograph in preparation for the Palæontographical Society, we have found that the species which we proposed to name *Ceratiocaris attenuata* (Fourth Report, Brit. Assoc. Rep. for 1886, p. 230) is really the same as *C. tyrannus*, Salter MS., and of course we adopt the latter name.

The term *lata* having been already applied to a species of *Ceratiocaris*, we use the designation *patula* for the little Lower-Ludlow form named *lata* in our Fourth Report.

§ II. SCANDINAVIAN PHYLLOCARIDA.—Some *Phyllocarida* from the Silurian strata of Scandinavia (Sweden and the island of Gothland) are represented by specimens in the State Museum at Stockholm. Drawings, casts, or the specimens themselves have been shown to us by our friend Professor Gustav Lindström, F.C.G.S., and we have arrived at the following conclusions as to their relationships [all except the first (*Ceratiocaris Angelini*) are from Upper-Silurian strata]:—

1. *Ceratiocaris Angelini*, sp. nov.—A long, stout, trifid caudal appendage, consisting of the style or telson (145 mm. long, and 17 mm. broad at the top) and two stylets (each 75 mm. long) lying close together. One of the latter has been broken across by a crush, and the former is not quite perfect at the tip (possibly 15 mm. longer or more originally). The lower (ventral) surface only is shown. The articulation of the stylets with and beneath the shoulders of the style—that is, under the backward extension or overhanging hinder edge of its head or proximal end—is very distinct. The upper edge of this part of the style (the surface articulating with the ultimate segment) has an undulated profile, with two small, projecting, asymmetrical, curved, horn-like processes.

The style on thisits lower aspect has a deep groove along the middle

of its upper moiety (obscured at the top), becoming narrow lower down. A slight groove on each side is also present. No delicate ridging is seen, nor any pits for bases of prickles. The stylets are smooth, and apparently subtriangular in section, each bearing one strong ridge on the upper part of the under face (as exposed).

In these features this form differs from *C. Bohemica*,[1] Barrande, the telson of which is not deeply furrowed on its ventral (under) face; and the latter species has longer stylets, oval in section, and neatly ridged throughout.

The Scandinavian specimen occurs, as an impression, in hard black shale ('Brachiopod-Skiffer') from the Lower-Silurian (Upper-Caradoc) of Westergötland (Westrogothia), a province in the western part of the mainland of Sweden. It has been badly figured in Angelin's unpublished 'Tab. LIII.' (figs. 18 and 19).

All the following are from the Upper-Silurian :—

2. *C. Bohemica*, Barr.—Portions of the shafts of straight, strong styles (telsons), similar to that of *C. Bohemica*, and chiefly from the middle and lower parts of the styles. In section these Scandinavian specimens are not so oblong as in Barrande's figs. 7 and 9 (pl. 19, 'Syst. Sil. Bohême,' vol. i. Suppl.), and the ridging on the lower face is somewhat stronger. (One piece=fig. 5 of Angelin's unpublished Table B.)

From the cream-coloured limestone (Wenlock Shale) of Eksta, Gothland.

3. A piece of telson of the same kind as the above. Shown by a drawing from Stockholm. From the (Wenlock Shale) Sandstone of Bursvik, South Gothland.

4. *C. Bohemica*, Barr., var. ?—A fragment of strong thick telson in cream-coloured limestone, differing from *C. Bohemica*: (1) in being curved (the convexity being dorsal, on the upper surface), (2) in having the two pitted ridges lower down on the side, and (3) in the under surface being more strongly ridged than in *C. Bohemica*. In some respects it approaches *C. valida*, J. and W. In whitish limestone with Strophomena, Trilobites, Tentaculites, Encrinites, &c. (Wenlock Limestone), from Rone, Gothland.

5. *C. Bohemica*, var. ?—A small fragment from Lau, Gothland, in cream-coloured fossiliferous limestone (Wenlock). It tapers rather rapidly, bears several thin ridges, and is oval in section. It may be a part of a stylet of some variety of *C. Bohemica*, for that species has its stylets ridged throughout.

6. *Ceratiocaris*, sp. nov. ?—A fragment of a style or a stylet. It is somewhat like the last (5), but the ridges are fewer, broader, and rounded. This is a drawing sent from Stockholm. The specimen (Mus. Geol. Survey, Sweden) was from Fröjel, Gothland (Wenlock Shale).

7. *Ceratiocaris concinna*, sp. nov.—A small portion of a straight, rapidly tapering style, convex on the upper, and concave along the lower face, with a half-moon-shaped section in the upper, and more oblong in the lower part. Two rows of small pits along the back, one on each side of the raised middle. The test is of a dull, light chesnut tint; it is hollow and filled with limestone. From Fröjel, Gothland. This tapering telson (7 mm. broad at the top, and $4\frac{1}{2}$ mm. at the end of the fragment 15 mm. long)

[1] *Syst. Sil. Bohême*, vol. i. Supplement, p. 447, pl. 19, figs. 1–13.

differs from any we know of, though it approaches that assigned to *C. patula*, J. and W. It is very neat in aspect and might be called *concinna*.

8. *C. Scharyi*, Barrande, var.—Seven abdominal segments (first and last imperfect), some with the test, some shown only by impressions; crushed laterally, and showing the whole half from the back to the epimeral border. In shape they are not unlike those of *C. Scharyi*, Barrande. They are ornamented with a strong leaf-like lattice-pattern, as in that species, but the lattice-pattern dies out into irregular oblique lines on the lower part of each segment (as in *C. stygia*, &c.), instead of being continued all over it as in *C. Scharyi*; nor is the smaller (secondary) lattice-work inside each leaf-mark so distinct as in that species, but presents merely a wrinkled appearance. (This is part of fig. 1 in Angelin's unpublished Table B.)

In hard blue micaceous shale (Ludlow), from the lake Ringsjön, Scania.

9. *Ceratiocaris pectinata*, sp. nov.—A portion of an ultimate segment (14×6 mm.), with a telson (fragment 30 mm.) and one stylet (not quite perfect, 22 mm.). The segment retains scarcely any of the test, but shows traces of an ornament of irregular small tubercles and interrupted longitudinal lines, and the distal margin of the segment has a coarse comb-like fringe, consisting of a regular set of thin elongate tubercles, reminding us of the drop-like tubercles on marginal parts of some Eurypterids. (Fig. 2 in Angelin's unpublished Table B.)

The head of the telson is wrinkled longitudinally, and both the style and the stylet are ridged and furrowed. This form is new to us. Its comb-like fringe suggests the name *pectinata*.

In earthy micaceous blue-grey limestone, from the Ringsjön, Scania.

10. *Phasganocaris*, Novák.—*Phasganocaris pugio* (Barr.), var. *serrata*, nov.—Flattened pieces of tapering, riband-like telsons, with a central line, sometimes raised, but usually sunken, which was originally a ridge in all probability. From it, on each side, numerous parallel, oblique, sigmoid lines pass downwards and outwards, and these end at the edges with sharp upward curves, defining the small subtriangular teeth of a serrated fringe. This is of varying strength, and is sometimes backed by a slight ridge. Except in the serrated edges these specimens correspond in essential particulars with the *dorsal* aspect of the triangular or bayonet-like lower portion of the telsons referred by Barrande to *Eurypterus*,[1] but by O. Novák, lately and with precision, to his new genus *Phasganocaris*.[2]

The fragments, dark brown and chitinous in appearance, are in an earthy yellowish grey limestone (Lower-Ludlow) from Vattenfallet (the Waterfall), near Wisby, Gothland.

11. *Phasganocaris pugio* (Barr.), var. *serrata*, nov.—A longer and narrower piece of a telson, badly preserved, much crushed and wrinkled, but retaining some convexity, and its upper end showing a slightly triangular section. Dark brown and chitinous, in a blue-grey, calcareous, and finely micaceous shale (Ludlow), from the Ringsjön, Scania.

§ III. Dithyrocaris.[3]—This genus, as recognised by its carapace and abdominal appendages, is now known in three of the Palæozoic formations,

[1] E. pugio, Barr., *Sil. Syst. Bohême*, vol. i. Suppl. p. 564, pl. 26, figs. 25–34, and pl. 34, figs. 7–9.

[2] Ph. pugio, Novák, *Sitzungsb. k. böhm. Gesell. Wissensch.*, 1886, pp. 1–4, pl. 1.

[3] Referred to in the First Report, 1883, *Brit. Assoc. Reports for* 1883, p. 216.

namely, the Upper and the Lower Carboniferous (especially in the latter), and the Devonian, of Europe, the British Isles, and North America. The following list indicates the geological horizons and the localities. There are two species from the Coal-measures of the United States, twelve from the Lower-Carboniferous of the Continent and British Isles (chiefly from Lanarkshire in Scotland), and six Devonian species.

DITHYROCARIS, Scouler, 1843.

Argas, Scouler, 'Records of General Science' (Thomson's), vol. i. 1835, p. 136.

Dithyrocaris, Scouler in Portlock's 'Geol. Report Londonderry, &c.,' 1843, p. 313.

Dithyrocaris, M'Coy, 'Ann. M. N. H.' ser. 2, vol. iv. 1849, p. 395.

Dithyrocaris, Morris, 'Catal. Brit. Foss.,' 1854, p. 107.

Dithyrocaris, Woodward and Etheridge, 1870, 1873, 1879, &c.

Dithyrocaris and *Argus* [*Argas*], Packard, 'Monogr. Phyll. Americ.,' 1883, p. 451.

I. UPPER-CARBONIFEROUS SPECIES OF DITHYROCARIS.

1. *Dithyrocaris carbonaria*, M. and W., 1873.

Dithyrocaris (?) *carbonarius*, Meek and Worthen, 'Geol. Survey of Illinois,' vol. v. (Geology and Palæontology), 1873, p. 618, pl. 32, f. 1*a*, 1*b*.

D. carbonaria, Miller, 'Catal. Pal. Foss. Amer.,' 1877, p. 217.

Carboniferous.—Middle Coal-measures, Danville, Illinois.

2. *Rachura* [probably *Dithyrocaris*] *venosa*, Scudder, 1878, 'Proceed. Boston Soc. Nat. Hist.,' vol. xix. pp. 296, 297, pl. 9, f. 3, 3*a*; Packard, 'Monogr. N.-Amer. Phyll.,' 1883, p. 452.

Carboniferous.—Coal-measures; Danville, Illinois.

II.—LOWER-CARBONIFEROUS SPECIES OF DITHYROCARIS.

1. *Dithyrocaris tricornis*, Scouler, 1835.
   Argas tricornis, Scouler, 'Records of General Science' (Thomson's), vol. i. 1835, pp. 137, 141, fig. 2.
   Dithyrocaris tricornis, Morris, 'Cat. Brit. Foss.,' 1854, p. 107.
   D. tricornis, W. and E., 'Mem. Geol. Surv. Scotl., Expl. Sheet 23,' 1873, p. 99; 'Geol. Mag.,' 1873, pp. 483, 486, pl. 16, f. 2 and 3.
   Lower-Carboniferous.—One mile south-east of Paisley, Renfrewshire; East Kilbride, Lanarkshire.
2. *Dithyrocaris testudinea*, Scouler, 1835.
   Argas testudineus, Scouler, 'Records of General Science' (Thomson's), vol. i. 1835, pp. 137, 141, f. 3.
   Dithyrocaris Scouleri, M'Coy, 'Syn. Carb. Foss. Irel.,' 1844, p. 163, pl. 23, f. 2.
   D. testudineus, Morris, 'Catal. Brit. Foss.,' 1854, p. 107.
   D. testudineus, W. and E., 'Mem. Geol. Surv. Scotl., Expl. Sheet 23,' 1873, p. 98; 'Geol. Mag.,' 1873, p. 482, pl. 16, f. 1.
   D. testudineus, Etheridge, 'Q. J. G. S.,' xxxv. 1879, p. 465, pl. 23, f. 1
   Lower-Carboniferous.—Near Paisley, Renfrewshire; East Kilbride, Lanarkshire; New Castleton, Roxburghshire.
3. *Dithyrocaris Colei*, Portlock, 1843.
   'Geol. Report Londonderry, &c.,' 1843, pp. 314, 565, 570, &c., pl. 12.

(Specimens.) Mus. Pract. Geol. $\frac{36}{7}$ = f. 4 and f. 5; $\frac{36}{8}$ = f. 1 and f. 6.

Mus. Pract. Geol. D $\frac{36}{3}$ = f. 2; 'Catal. Sil. Cambr. Foss., M. P. G.,' 1865, p. 116.

Lower-Carboniferous.—Tyrone Shales; Clogher, Ireland.
Derry Shales; Ballynascreen, Ireland.
Carboniferous Limestone, Lower Shales; Clogher, Tyrone.
Lower-Carboniferous; Craigenglen, near Glasgow; *fide* 'Catal. W.-Scot. Foss.,' 1876, p. 45.

4. *Dithyrocaris orbicularis*, Portlock, 1843.
'Geol. Report Londonderry, &c.,' 1843, p. 316 (not figured).
Lower-Carboniferous.—Ballynascreen Shale; Whitewater River, Derry.

5. *Dithyrocaris tenuistriata*, M'Coy, 1844.
Avicula paradoxoides? De Koninck, 'Descript. Anim. Foss. Carb.,' 1842, p. 139, pl. 6, f. 6.
Dithyrocaris tenuistriatus, M'Coy, 'Synops. Carbonif. Foss. Ireland,' 1844, p. 164, pl. 23, f. 3.
D. tenuistriatus, H. W., 'Report Brit. Assoc.,' August 1871. 'Geol. Mag.,' 1871, p. 106, pl. 3, f. 4.
Morris, Packard, &c.
(Specimens.) *Lower-Carboniferous.*—Visé, Belgium; Robroystone, Lanarkshire.
Lower-Carboniferous.—Ireland (no locality given); Robroystone (?) and Auchenbeg, Lanarkshire, Scotland; Mountain-limestone, Settle, West Yorkshire.

6. *Dithyrocaris lateralis*, M'Coy, 1852.
'Brit. Pal. Foss. Cambridge Mus.,' 1852, p. 182, pl. 3 I, f. 36.
The figure here referred to does not well represent the specimen in the Cambridge University Museum (W. Hopkins, Coll.).
Lower-Carboniferous.—From the black bands over the main limestone of Derbyshire.

7. *Dithyrocaris granulata*, Woodward and Etheridge, 1873.
'Mem. Geol. Surv. Scotl., Expl. Sheet 23,' 1873, p. 99.
'Geol. Mag.,' 1874, p. 108, pl. 5, f. 2 and 3.
Lower-Carboniferous.—East Kilbride, Lanarkshire.

8. *Dithyrocaris glabra*, W. and E., 1873.
'Mem. Geol. Surv. Scotl, Expl. Sheet 23,' 1873, p. 99.
'Geol. Mag.,' 1874, pp. 108, 109, pl. 5, f. 4 and 5.
Lower-Carboniferous.—East Kilbride, Lanarkshire; and Ardross Castle, Fife.

9. *Dithyrocaris ovalis*, W. and E., 1873.
'Mem. Geol. Surv. Scotl., Expl. Sheet 23,' 1873, p. 100.
'Geol. Mag.,' 1874, p. 107, pl. 5, f. 1.
Lower-Carboniferous.—East Kilbride, Lanarkshire.

10. *Dithyrocaris*, sp. indet. Etheridge, 'Q. J. G. S.,' xxxv. 1879, p. 465.
Lower-Carboniferous.—Wardie Shales of the Calciferous-sandstone series, near Edinburgh.

11. *Dithyrocaris*, sp. indet. Etheridge, 'Q. J. G. S.,' xxxv. 1879, p. 466, pl. 23, f. 2 and 3.
Lower-Carboniferous.—Cement-stone group, near New Castleton, Roxburghshire.

12. *Dithyrocaris*, sp. indet. Etheridge, 'Q. J. G. S.,' xxxv. 1879, p. 467.
Lower-Carboniferous.—Cement-stone group, near New Castleton, Roxburghshire.

Specimen Formerly Referred to Dithyrocaris.

[*Dithyrocaris*] *pholadomya*, Salter MS., 1863, 'Quart. Journ. Geol. Soc.,' vol. xix. 1863, p. 92, note.

D. pholadomyia, Packard, 'Monogr. Phyllop. N. America,' 1883, p. 452.

(Specimen.) Mus. Pract. Geol. D $\frac{36}{2}$, marked '*Dithyrocaris pholadiformis*,' Salter MS. In a dark micaceous sandstone of the Lower-Carboniferous Limestone, Berwick-upon-Tweed. 'Catal. Sil. Cambr. Foss. M. P. G.,' 1865, p. 116.

This specimen is probably allied to *Saccocaris*, Salter (1868 and 1873), First Report 'Pal. Phyll.,' 1883, p. 219.

III. Devonian Species of Dithyrocaris.

1. *Dithyrocaris ? striata*, W. and E., 1873.
'Mem. Geol. Surv. Scotl., Expl. Sheet 23,' 1873, p. 100.
'Geol. Mag.,' 1874, pp. 109, 110, pl. 5, f. 6.
'Catal. W.-Scot. Foss.,' 1876, p. 27.
Devonian.—Lower Old Red Sandstone; Carmichael Burn, $4\frac{1}{2}$ miles S.E. of Lanark.
2. *Dithyrocaris Belli*, H. Woodward, 1871.
D. striata, H. W., 'Brit. Assoc. Rep.,' 1870, sect. p. 90.
D. Belli, H. W., 'Geol Mag.,' 1871, p. 106, pl. 3, f. 5.
—— 'Brit. Assoc. Report,' August 1871.
—— Miller, 'Catal. Pal. Foss. Amer.,' 1877, p. 217.
D. striata, Bigsby, 'Dev.-Carb. Thesaurus,' 1878, p. 27.
D. Belli, Packard, 'Monogr. N.-Amer. Phyll.,' 1883, p. 452.
Devonian.—Middle-Devonian; Gaspé.
It is possible that the figure represents two opposite valves, reversed and overlapping on their inner margins.
3. *Dithyrocaris Neptuni*, Hall, 1863.
'Sixteenth Annual Report New-York State Museum,' 1863, Appendix D, p. 75, pl. 1, f. 9.
'Palæont. New York,' vol. v. Part II.; 'Illustrations of Devonian Fossils,' 1876; pl. 22, f. 1–5, carapace and spines, Portage Group; pl. 23, f. 1–6, tail-spines, Hamilton and Portage Groups.
Miller, 'Catal. Pal. Foss. Amer.,' 1877, p. 217, 'Chemung Group.'
Packard, 'Monogr. N.-Amer. Phyll.,' 1883, p. 452, woodcut, f. 73.
Upper (and Middle ?) Devonian.—Hamilton and Portage Groups.
4. *Dithyrocaris Kochi*, Ludwig, 1864.
'Palæontographica,' vol. xi. p. 309, pl. 50, f. 1*a*, 1*b*, 1*c*.
Devonian.—Near Herborn, in the Dillthal, Nassau.
5. *Dithyrocaris breviaculeata*, Ludwig, 1864.
'Palæontographica,' vol. xi. p. 310, pl. 50, f. 2.
Devonian.—Spirifer-sandstone Series, near the Butzbach, Nassau.
6. (Specimen.) Near *D. tenuistriata*, M'Coy; from the Cypridinen-Schiefer, near Saalfeld.

IV. Silurian Specimens Formerly Referred to Dithyrocaris.

1. [*Dithyrocaris*] *aptychoides*, Salter, 1852
 = *Peltocaris aptychoides*, Salter, 1863. See the Second Report on the Palæozoic Phyllopoda, 1884, p. 92.
 Silurian.—Moffat, Scotland.
2. [*Dithyrocaris*] *Murchisoni*, Geinitz, 1853.
 Ceratiocaris Murchisoni (Agass.). See the Third Report on Palæoz. Phyllop., p. 340.
 Silurian.—Saxony.
3. [*Dithyrocaris* ?] *longicauda*, D. Sharpe, 1853.
 D. ? *longicauda*, D. Sharpe, 'Q. J. G. S.,' vol. ix. p. 158, pl. 7, f. 3.
 Ceratiocaris ? *longicauda*, Jones and Woodward. Third Report on Palæoz. Phyllop. 1885, p. 354.
 Silurian.—Near Bussaco, Portugal.
4. [*Dithyrocaris*] *Jaschei*, F. A. Römer, 1855.
 'Palæontographica,' vol. v. p. 8, t. 2, f. 13; and vol. xiii. 1866, p. 219, referring to Römer's 'Beitrag III. 17. 13' (misspelt 'Ditryocharis').
 [*Dithyrocaris*] *Jaschei*, Römer. Kayser, 'Abhandl. Geol. Speciälkarte von Preussen und Thüringischen Staaten,' vol. ii. Heft 4, 1878, p. 7, t. 1, f. 13, 13*a*.
 Silurian.—Near Ilsenberg, Hartz.
 Referring to Römer's 'Beitrag III., p. 120, t. 17, f. 2,' and giving more correct figures of the exterior and section. Doubtfully like a portion of a bivalved carapace, filled with matrix and broken across.

Kayser, *ibid.* p. 8, t. 1, f. 14, also describes and figures a dubious fossil from the oldest *Devonian* rocks of the Hartz (the limestone of the Upper Sprakelbach), which, Kayser says, looks like a tail-spine of a *Ceratiocaris*; such, for instance, we may add, as *C. pernornata*, Salter; see our Third Report, p. 352. It may, however, have belonged to a Placoid fish, as Kayser observes. A fragment of what may have been the valve of a *Nothozoe* (*ibid.* p. 9, t. 1, f. 15) was found in the same limestone.

§ IV. Leaia.—Since the genus *Leaia* (mentioned in our First Report, 1883, p. 217) was established in the 'Monograph of Fossil Estheriæ,' Pal. Soc., 1862, Appendix, p. 116, some other forms besides *L. Leidyi* have been recorded; and several additional localities have been noticed, both for that species and *L. Williamsoniana* and *L. Salteriana*, described originally as varieties. The original description of the genus and of *Leaia Leidyi* (Lea) has been reproduced in Dr. A. S. Packard's 'Monograph of North-American Phyllopod Crustacea,' 1883, pp. 356–358.

In 1870 the history and nature of the genus *Leaia* were fully treated of by H. Laspeyres in the 'Zeitschr. deutsch. geol. Gesellsch.,' vol. xxii. pp. 773, &c., with definite descriptions and good figures of five forms as specific types, distinguished by shape, proportions, and ornament—namely, *L. Leidyi*, Lea, p. 743, t. 16, f. 3 *L. Williamsoniana*, Jones, p. 743 t. 16, f. 4; *L. Baentschiana*, Beyr. and Gein., p. 744, t. 16, f. 2; *L. Wettinensis*, Laspeyres, p. 745, t. 16, f 1; and *L. Salteriana*, Jones, p. 744, t. 16, f. 5, the second, third, and fifth having previously been treated as varieties by their describers. This paper is noticed in the 'Neues Jahrb.,' 1870, p. 922.

Goldenberg, in his 'Foss. Thiere Steinkohl. Saarbrücken,' Heft. II. 1877, redescribed, with some figures, *L. Leidyi* and varr. *Williamsoniana* and *Salteriana*, Jones, p. 45, t. 2, f. 22, 33, adding an account of other forms.

In 1879 R. Etheridge, jun., gave a synopsis of the foregoing genus and species, with full references, in the 'Ann. Mag. Nat. Hist.,' ser. 5, vol. iii. p. 262, with the addition of the species *L. Jonesii.*

All the known species of *Leaia* have been found in the Carboniferous series or in strata in close apposition above or below, as shown in the following list:—

1. 1862.—*Coal-measures* of South Wales, and the *Lowest-Carboniferous* or *Uppermost-Devonian* of Pennsylvania.

Leaia Leidyi (Lea), Jones, 'Monogr. Foss. Esth. Pal. Soc.,' 1862, Appendix, p. 116, pl. 5, f. 11, 12. Figured also by Laspeyres and Goldenberg.

2. 1862.—*Coal-measures* near Manchester and South Wales.

Leaia Williamsoniana, Jones. As a variety of *L. Leidyi*, *ibid.* p. 117, pl. 1, f. 19, 20. Figured also by Goldenberg.

3 1862.—*Coal-measures* of South Wales (?), and *Lower Carboniferous* of Fife.

Leaia Salteriana, Jones. As a variety of *L. Leidyi*. *Ibid.* p. 119, pl. 1, fig. 1. Figured also by Laspeyres and Goldenberg.

In the 'Geol. Mag.,' vol. vii. 1870, p. 219, doubts were expressed as to these forms being specifically distinguishable, but in view of H. Laspeyres' careful conclusions it may be right to treat the so-called varieties as distinct species.

4. 1864.—Lower Permian ('Lower Dyas'); Werschweiler, near Neunkirchen, not far from Saarbrücken, in the Treves district, Rhenish Prussia.

Leaia Bœntschiana, Beyrich and Geinitz, was so named as a variety of *L. Leidyi* by Beyrich, and as a species by Geinitz independently in 1864; Beyrich's note, 'Zeitschr. deutsch. geol. Gesellsch.,' vol. xvi. 1864, p. 364, bearing a rather earlier date than Geinitz's descriptive note in the 'Neues Jahrb.,' 1864, p. 657, and his fuller description in the 'N. Jahrb.,' 1865, p. 389, t. 2, f. 2 A, *a*, & 3 A, *a*.

In his paper on Von Dechen's Geological Map of the Saarbrücken Coal-field, &c., Dr. Weiss first noticed this fossil as being either a *Posidonomya* or an *Estheria*, of a peculiar goose-foot shape, 'N. Jahrb.,' 1864, p. 656.

In 1870 this species was carefully redescribed and well figured by H. Laspeyres, 'Zeitschr. d. g. Ges.,' vol. xxii. p. 744, t. 16, f. 2, as *L. Bœntschiana.*

In 1873 and 1877 M. Goldenberg included this interesting fossil in his 'Fauna Saræpontana fossilis,' Heft I. p. 24, t. 1, f. 20, 21, and Heft II. p. 46, t. 2, f. 24, as a variety of *L. Leidyi.*

In his 'Handbuch der Paläontologie,' vol. i. Part 8, 1885, p. 568, fig. 758, Zittel gives both *Leaia Leidyi*, J. (after Jones), and *L. Bœntschiana*, Geinitz (after Goldenberg), but they are wrongly referred to in the text.

5. 1868.—*Coal-measures.* Illinois. *Leaia tricarinata*, Meek and Worthen, 'Geol. Survey Illinois,' vol. iii. Geology and Palæontology, pp. 541–43, woodcuts on p. 540 (with *Colpocaris*), figs. B1, B2, B3, and C.

6. 1870.—*Coal-measures.* Wettin, Prussian Saxony, on the Saale. *Leaia Wettinensis*, Laspeyres, 'Zeitschr. deutsch. geol. Gesellsch.,' vol. xxii. p. 745, t. 16, f. 1; 'N. Jahrb.,' 1870, p. 922.

7. 1873 and 1877.– *Coal-measures.* Saarbrücken, Rhenish Prussia. *Leaia Leidyi*, var. *Klieveri*, Goldenberg. 'Fauna Saræp. foss.' or 'Foss. Thiere Steinkohl. Saarbrücken,' Heft I. 1873, p. 24, t. 1, f. 22; *L. Klieveriana*, *ibid.* Heft II. 1877, p. 46, t. 2, f. 20, 21.

8. 1879.—*Lower-Carboniferous* series (Wardie Shales), near Edinburgh. *Leaia Jonesii*, R. Etheridge, jun., 'Ann. Mag. Nat. Hist.,' ser. 5, vol. iii. p. 260, woodcuts, figs. 1 and 2.

9. Other localities for *Leaia* (all in the *Lower-Carboniferous* series) have been noticed:—

Ironstone of the Wardie Shales, near Edinburgh, 'Geol. Surv. Scotl., Expl. Sheet 32,' 1861, pp. 30, 31; 'Geol. Mag.,' viii. 1871, p. 96; 'Report Brit. Assoc.' for 1871, sections, p. 109; 'Q. J. G. S.,' vol. xxxiv. pp. 5, 23.

Ironstone at Clifton (under the eastern end of York Crescent, near the Post Office), Bristol. *Fide* Mr. R. S. Roper and Mr. W. Adams.

Ironstone near (north of) Wemyss, Fife. 'Geol. Mag.,' 1874, p. 480.

Lower-Carboniferous Shales, Nova Scotia, 'Geol. Mag.,' vol. ii. 1865, p. 60; 'Acadian Geology' (J. W. Dawson), 1st edit. 1868, and 3rd edit. 1878, pp. 131 and 256, fig. 78 *e*. *Leaia Salteriana*?

§ V. Palæozoic Estheriæ.—The following species are known:—

1. Permian.

Estheria exigua (Eichwald, 1846), Jones, 1862. Russia.

E. tenella (Jordan, 1850), Jones, 1862. Saxony; Russia.

E. nana (Ludwig, 1861), Geinitz, 1864. Not *E. nana* (De Koninck). Germany.

E. Portlockii, Jones, 1862. Ireland.

E. rugosa, Gümbel, 1864. Thuringia.

2. Upper-Carboniferous.

Estheria striata (Münster, 1826), Jones, 1862. Bavaria; Belgium; England.

Estheria nana (De Koninck, 1842), Geinitz, 1864. Liége, Belgium.

E. tenella (Jordan, 1850), Jones, 1862. England; Scotland; South Wales; France (?); Germany; Spain.

E. striata, var. *Beinertiana*, Jones, 1862. England; Silesia.

—— var. *Binneyana*, Jones, 1862, England.

E. Adamsii, Jones, 1870. South Wales.

E. limbata, Goldenberg, 1877. }
E. rimosa, Goldenberg, 1877. } Saarbrücken, Rhenish Prussia. The coal-beds here are regarded by some geologists as of Permian age.

E. Freysteini, Geinitz, 1879. Saxony.

3. Lower-Carboniferous.

E. striata, var. *Beinertiana* Jones, 1862. Lanarkshire, Scotland.

—— var. *Tateana*, Jones, 1862. Berwickshire, Scotland.

E. punctatella, Jones, 1865. Lanarkshire, Scotland.

E. Dawsoni, Jones, 1870. (Not *E. Dawsoni*, Packard, 1881 and 1883.) Nova Scotia.

E. Peachii, Jones, 1870. Edinburgh, Scotland.

E. striata, var. *tenuipectoralis*, Jones, 1883. Western Siberia.

E. Nathorsti, Jones, 1883. Possibly of Upper-Devonian age. Spitzbergen.

4. DEVONIAN.

Estheria membranacea (Pacht, 1849), Jones, 1862.

E. pulex, Clarke, 1882. Western part of the State of New York.

This last-mentioned *Estheria* is very small, but in shape it is somewhat like the recent *E. compressa*, Baird. In its shape it also approximates to *E. rimosa*, Goldenberg, 'Foss. Saarbrück.,' Part II. t. 2, f. 18; and to *E. triangularis*, Emmons.

Professor Dr. F. M'Coy long ago intimated that some fossils described as belonging to the Mollusca may really be Entomostraca, 'Synops. Carbonif. Foss. Ireland,' 1842, p. 164. Some suggestions in this direction were offered in the 'Monogr. Foss. Estheriæ,' 1862, p. 13.

It may be useful to notice that it is highly probable that, as Geinitz has suggested ('Neues Jahrb.,' 1864, p. 654), the *Cardinia nana* of De Koninck, 'Foss. Carbonif. Belg.,' p. 71, t. 1, f. 6 *a*, *b*, is an *Estheria* (referred to also in the 'Monograph Esth.,' *l.c.*). It was taken from the coal-shale at the Battery Coal-pit, near the citadel at Liége.

The *Cyclas nana*, Ludwig, 'Palæontographica,' vol. x. 1861, p. 21, t. 3, f. 10, from strata regarded as Permian (Dyadic) by Gümbel, near Manebach, not far from Ilmenau in Sachsen-Weimar, is also probably an *Estheria*. See Geinitz, 'N. Jahrb.,' 1864, p. 654; also Karl von Fritsch, 'Zeitschr. d. g. Ges.,' vol. xii. 1860. This little fossil Ludwig thought to be the same as the *Cardinia nana* of De Koninck; but it is evidently very different in shape, being nearly orbicular, whilst the other is obliquely sub-elliptical.

Pullastra ? striata in Portlock's 'Report Geol. Londonderry, &c.,' p. 440, t. 36, f. 13, has somewhat the aspect of an *Estheria*. This form will have to be carefully studied in connection with *E. Adamsii*, *E. punctatella*, and other punctate shells, formerly looked upon as Molluscan, before definite conclusions can be arrived at.

ADDENDUM.

Professor C. Malaise, of Gembloux, has to-day shown us several specimens of *Caryocaris*[1] *Wrightii* (?) from the Lower-Silurian (Cambrian) slates of Huy and Nannine, Belgium; and with one of them is an undoubted trifid caudal appendage. Each of the three spines is sharply lancet-shaped, and they are of nearly equal size.—August 17, 1887.

[1] See the First Report, 1883, pp. 217 and 221.

Report of the Committee, consisting of Mr. JOHN CORDEAUX (*Secretary*), Professor A. NEWTON, Mr. J. A. HARVIE-BROWN, Mr. WILLIAM EAGLE CLARKE, Mr. R. M. BARRINGTON, *and* Mr. A. G. MORE, *reappointed at Birmingham for the purpose of obtaining (with the consent of the Master and Brethren of the Trinity House and the Commissioners of Northern and Irish Lights) observations on the Migration of Birds at Lighthouses and Lightvessels, and of reporting on the same.*

THE General Report[1] of the Committee has been printed in a pamphlet of 174 pages, and includes observations from 126 stations out of a total of 198 supplied with schedules, letters of instruction, and cloth-lined envelopes for wings; altogether 280 schedules have been sent in. In the last report attention was particularly directed to those main highways or lines of migration by which birds approach the east coast of Scotland both in the spring and autumn. Two chief lines seem to be clearly indicated, by the Pentland Firth and Pentland Skerries, also by the entrance of the Firth of Forth as far north as the Bell Rock Lighthouse. Continued observations also indicate that on the east coast of England the stream of migration is not continuous over the whole coast line, but seems to travel along well-established lines, which are persistently followed year by year.

On the east coast of England there seems to be a well-marked line, both of entry and return, of the Farn Islands, on the coast of Northumberland. Scarcely second to this in importance is the mouth of the Tees, both in the spring and autumn. The North Yorkshire coast and the elevated moorland district from the south of Redcar to Flamborough, including the north side of the headland, is comparatively barren, few birds appearing to come in. Bridlington Bay and Holderness to the Spurn and Lincolnshire, as far as Gibraltar Point, on the coast of Lincolnshire, give, perhaps, the best returns on the east coast. The north of Norfolk is poor, but there are indications, in the heavy returns annually sent from the Llynwells, Dudgeon, Leman and Ower, and Happisburgh Lightvessels, that a dense stream pours along the coast from E. to W., probably to pass inland by the estuary of the Wash and the river systems of the Nene and Welland into the centre of England, thence following the line of the Avon valley and the north bank of the Severn and Bristol Channel, and crossing the Irish Sea to enter Ireland at the Tuskar Rock, off the Wexford coast. This is apparently the great and main thoroughfare for birds in transit across England to Ireland in the autumn. Large numbers of migrants also which pass inland from the coasts of Holderness and Lincolnshire may eventually join in with this great western highway by the line of the Trent, avoiding altogether the mountainous districts of Wales. The Norfolk seaboard between Cromer and Yarmouth and the corresponding lightvessels show a large annual immigration, but the returns are much less, and comparatively meagre between Yarmouth and Orfordness. The coast of Essex, with the northern side of the Thames, is fairly good; but the coast of Kent, between the North and South Forelands, including

[1] *Report on the Migration of Birds in the Spring and Autumn of* 1886. McFarlane & Erskine, 19 St. James's Square, Edinburgh, price 2*s*.

the four Goodwin and the Varne lightships, is a barren and pre-eminently uninteresting district for arrivals, both as regards numbers and species, the chief migrants seen being such as are apparently following the coast to the south.

Such migrants, both local and otherwise, which in the autumn follow the east coast from north to south, seem, as a rule, to pass directly from the Spurn to the Lincolnshire coast without entering the Humber; and there are no indications that they follow the shores of the Wash in and out, but shape their course from about Gibraltar Point to the Norfolk coast. The well-filled schedules sent in annually from the Shipwash, Swin Middle, Kentish Knock, and Galloper Lightships indicate that a stream passes from the south-east coast of Suffolk across the North Sea in the line of these stations, to and from the Continent, both in the spring and autumn.

Autumn migrants approaching the Humber from the sea do not appear to follow the course of the river into the interior, that is, from S.E. to N.W. The line would seem to cross the river diagonally, and is from E.S.E. to W.N.W. This course is so persistently followed that year by year, on such days when migration is visible, birds are observed to cross the same fields and at the same angle. Supposing this course to be continued, they would strike the Trent at or near Gainsborough.

Much information has been obtained from the legs and wings sent in the envelopes provided for that purpose; and by this means already several rare and unusual wanderers have been recorded, not the least interesting being the occurrence of a small Asiatic species, the yellow-browed warbler, at Sumburgh Head, Shetland, on September 25, and an immature example of the American red-winged starling, at 3 A.M. on October 27, at the Nash Lighthouse, Bristol Channel. This station, situated on the coast of Glamorgan and on the north side of the Bristol Channel, lies directly in the track of the great highway followed by migrants from England to Ireland. The black redstart was killed at the Nash Lighthouse on the night of October 29; and another interesting occurrence was that of the green woodpecker, seen on October 26, with many other birds at sunrise passing to the S.E.[1] The black redstart was also received from the Fastnet, co. Cork, found dead on October 30. It is also recorded at four other stations on the south coast of Ireland, and its regular occurrence in the winter on the south and east coasts of that island has now been fully established by this inquiry. The regular occurrence in migration of the black redstart both off and on the east coast of England, as well as the example from the Nash Lighthouse, are suggestive of the route followed annually by some small portion of this Continental species, which curiously select as their winter quarters the south-west coasts of the British Islands. From the Irish coasts the rarities received were numerous, including the second Irish specimen of the wryneck from Arran Island, co. Galway, killed striking 2 A.M. on October 6.

[1] Mr. H. Nicholas, of the Nash [East] L. H., under date of September 3, has recorded an enormous arrival of small birds—the greatest number ever seen there at any one time. These include four nightjars at 2.10 A.M., one killed; fifteen to twenty common buntings from 2.15 to 3 A.M., eight killed; fifty to sixty greater whitethroats from 2.15 to 3 A.M., twenty-four killed; twenty to thirty willow wrens from 2.30 to 3.20 A.M., seventeen killed; six young cuckoos at 3 A.M., two killed; fourteen house sparrows and one robin killed at 3 A.M.; thirty to forty wheatears at 3.10 A.M. two killed; three blackbirds from 3 to 3.15 A.M., one killed.

From the Tearaght, co. Kerry, a pied flycatcher was caught at the lantern, September 21, the species only having once before occurred in Ireland—in April 1875. The repeated occurrence of the corncrake, several miles from shore—killed striking against lanterns between 100 to 200 feet above sea-level—must satisfy the sceptical that this well-known species can fly at a high level with great power and velocity. The waterrail, which seems so unwilling to fly, was received from the Fastnet and Tuskar on October 26 and 28; also from Spurn L. V., November 1, one; Llyn Wells L. V., November 4, two; and Coquet Island L. H., same date, one; showing a widely extended migratory movement of this species during the last week in October and early in November.

The great spotted woodpecker occurred in considerable numbers in the eastern counties of Scotland about the middle of October. Almost all the specimens examined were either old birds or with very slight traces of immaturity. This immigration extended southward to the coast districts of Lincolnshire, where very considerable numbers were obtained in the autumn and winter.

At Rathlin O'Birne (West Donegal) immense flocks of birds—starlings, thrushes, and fieldfares—passed *west* from December 18 to 23. The nearest land to the west of this rocky island is America. This is not an isolated occurrence. The westerly flight of land-birds at stations off the west coast of Ireland has been noticed on other occasions; the movement is apparently as reckless as that of the lemmings.

The autumnal passage of quails from England is shown by their occurrence at the Smalls L. H., September 3, and the Eddystone on October 5; also a wing from the Shipwash L. V., off the Essex coast, obtained on October 26.

An enormous rush of immigrants is recorded from the east coast of England on October 4, 5, and 6, with easterly and south-easterly winds, pressure system cyclonic, but the adverse meteorological conditions during this period slowly passing away. Much fog and thick weather at the time, which in a great measure may account for the immense numbers of birds seen at the lanterns of lighthouses. The movement was less apparent on the east coast of Scotland, the winds being E.N.E. and N.E., having a tendency to crush down migration, giving it a more southerly direction. On the west coast of Scotland, during the same period, at the majority of stations the rush of birds was enormous; but the movement was much less accentuated on the west coast of England, and to a less degree still on the Irish coasts. The rush is by far the largest ever recorded since the opening of this inquiry.

As usual on the east coast of England, rooks, daws, hooded crows, starlings, and larks occupy a considerable portion of the returned schedules. Chaffinches have crossed the north sea in extraordinary numbers. They are always numerous, but this autumn the immigration has been in considerable excess of previous years. With these exceptions, however, there has been a singular and very marked falling off in the migration of some species whose breeding range lies chiefly in the north of Europe. This has been especially noticeable in the small arrivals recorded of fieldfares, redwings, ring-ousels, bramblings, snow-buntings, short-eared owls, and woodcocks.

Eight reports have now been issued by your Committee, and the stations have again been supplied with the necessary papers for the re-

turns of the observations in the present year. It seems highly desirable that an attempt should shortly be made to analyse, classify, and digest the large mass of facts brought together in these reports, so as to show, statistically and otherwise, the actual results which have been arrived at by the inquiry. It is intended that this shall be carried out at as early a date as possible.

The Committee respectfully request their reappointment.

Report of the Committee, consisting of H. SEEBOHM, R. TRIMEN, W. CARRUTHERS, *and* P. L. SCLATER (*Secretary*), *appointed for the purpose of investigating the Flora and Fauna of the Cameroons Mountain.*

THE Committee have the pleasure of reporting that a successful ascent of the Cameroons Mountain was made by Mr. H. H. Johnston, F.Z.S., F.R.G.S., H.B.M. Vice-Consul for the Cameroons, on their behalf in the autumn of 1886. Mr. Johnston encamped at Mann's Spring, at an altitude of 7,350 feet, about 300 feet above the forest region of the mountain, and remained there several weeks. A popular account of his expedition has been published with illustrations in the 'Graphic' newspaper.[1]

Mr. Johnston made considerable collections in zoology and botany. The zoological collections have been worked out by specialists in different branches, to whom the collections were referred by the Committee, and the results published in a series of papers in the 'Proceedings of the Zoological Society of London,' of which the following are the titles:—

1. 'List of Mammals from the Cameroons Mountain, collected by Mr. H. H. Johnston.' By Oldfield Thomas, Proc.Z.S., 1887, p. 121.
2. 'On a Collection of Birds made by Mr. H. H. Johnston on the Cameroons Mountain.' By Capt. G. E. Shelley, F.Z.S., Proc.Z.S., 1887, p. 122.
3. 'List of the Reptiles collected by Mr. H. H. Johnston on the Cameroons Mountain.' By G. A. Boulenger, Proc.Z.S., 1887, p. 127.
4. 'On the Mollusca collected at the Cameroons Mountain by Mr. H. H. Johnston.' By Edgar A. Smith, Proc.Z.S., 1887, p. 127.
5. 'On some Coleopterous Insects collected by Mr. H. H. Johnston on the Cameroons Mountain.' By Charles O. Waterhouse, Proc.Z.S., 1887, p. 128.

It will be observed that although the collections are small they are by no means devoid of interest. Out of eighteen species of birds of which examples were obtained four were new to science, and a new land shell, of the genus *Gibbus*, was also discovered.

The zoological specimens have been placed in the collection of the British Museum.

The botanical specimens collected by Mr. Johnston were sent by the Committee to the Kew Herbarium, where they were placed in Prof. Oliver's hands for determination. As was to be expected, although the specimens were in many cases acceptable, they have added very little to our knowledge of the flora of the Cameroons Mountain. With few ex-

[1] See 'An Ascent of the Cameroons Mountain.' By H. H. Johnston, F.R.G.S., F.Z.S., &c. (*Graphic.*)

ceptions all Mr. Johnston's species, of which a complete list is given in the appendix to this report, are enumerated in Sir Joseph Hooker's paper on Mann's Plants of the Cameroons, published in the 'Journal of the Linnean Society' in 1864. (Bot. vol. vii. p. 181.)

A complete set of the duplicates has been deposited in the Botanical Department of the British Museum, and a second set of duplicates has been sent to the Royal Museum of Berlin.

The sum of 75*l*., granted to the Committee at Birmingham, has been paid to Mr. Johnston as a contribution towards the expenses of his expedition.

The Committee ask to be reappointed, and a further sum of 100*l*. placed at their disposal, as Mr. Johnston will in all probability be able to undertake a second expedition up the Cameroons Mountain in the course of the present autumn.

APPENDIX.

List of Plants from the Upper Slopes of the Cameroons received at Kew from Vice-Consul H. H. Johnston, *December* 1886.

I. Phanerogams.

Clematis simensis, Fres.
Thalictrum rhynchocarpum, A. Rich.
Polygala tenuicaulis, Hook. f.
Silene Biafræ, Hook. f.
Cerastium africanum, Oliv.
Hypericum lanceolatum, Lam.
Geranium simense, Hochst.
" " var. *glabrior*.
Vitis Mannii, J. G. Baker.
Adenocarpus Mannii, Hook. f.
Trifolium simense, Fres.
Indigofera atriceps, Hook. f.
Desmodium scalpe, DC. (*D. strangulatum*, Wight and Arn.)
Rubus pinnatus, Wight and Arn.
Crassula abyssinica, A. Rich. (*C. Mannii*, Hook. f.)
Cotyledon Umbilicus, L.
Sanicula europæa, L.
Peucedanum sp. nov. ? (material inadequate)
Pimpinella ? " "
Caucalis melanantha, Bth. and Hook. f. (*Agrocharis*, Hook. f.)
Pentas occidentalis, Bth. and Hook. f. (*Vignaldia*, Hook. f.)
Diodia (*D. brevisetæ*, Benth. var. ? no fruit).
Galium Biafræ, Hiern (*G. rotundifolium*, Hook. f.).
" *Aparine*, L. var.
Dichrocephala chrysanthemifolia, DC.
Anisopappus africanus, O. and H.
Achyrocline Hochstetteri, S. Bip.
Helichrysum chrysocoma, S. Bip., var. *angustifolium*.
" *fœtidum*, Cass. var. (*H. Mannii*, Hook. f.)
" ? *sp. nov.* Technical character of *Gnaphalium*.
Coreopsis monticola, O. and H. (*Verbesina*, Hook. f.)
Gynura vitellina, Bth., var. *gracilis*.
Senecio Burtoni, Hook. f.

Senecio Clarenceana, Hook. f.
Crepis Hookeriana, O. and H. (*Anisoramphus*, Hook. f.)
Lactuca capensis, Thbg. ? inadequate.
Probably *Sonchus angustissimus*, Hook. f., inadequate.
Wahlenbergia arguta, Hook. f.
Agauria salicifolia, Hook. f.
Ericinella Mannii, Hook. f.
Blæria spicata, Hochst.
Sebœa brachyphylla, Griseb.
Swertia Mannii, Hook. f.
„ *Clarenceana*, Hook. f.
Cynoglossum lancifolium, Hook. f.
„ *micranthum*, Desf.
Myosotis intermedia, Link.
Solanum nigrum, L., forma (of Sir. J. Hooker's Enumeration of Mann's plants of Cameroons) *an sp. diversa* ?
Solanum nigrum, L. var.
Bartsia abyssinica, Hochst., small form.
Alectra senegalensis, Benth.
Sopubia trifida, var. *madagascariensis*, Hook. f., *l.c.*
Veronica Mannii, Hook. f.
„ *africana*, Hook. f.
Celsia densifolia, Hook. f. var. *pedicellis longioribus*
Isoglossa =Mann, 2009.
„ =Mann, 1972.
Oreacanthus Mannii, Benth.
Pycnostachys abyssinica, Hook. f., *non* Fresenius ?
Plectranthus, *sp. nov.* ? inadequate.
„ *decumbens*, Hook. f.
„ *glandulosus* ? Hook. f., imperfect.
„ *ramosissimus*, Hook. f.
Coleus glandulosus, Hook. f., inadequate.
Micromeria punctata, Benth.
Calamintha simensis ? Benth. (inadequate), forma.
„ *simensis*, Benth.
Nepeta robusta, Hook. f.
Stachys aculeolata, Hook. f.
Leucas oligocephala, Hook. f.
Achyranthes argentea, L.
Cyathula cylindrica, Moq., var.
Rumex abyssinicus, Jacq.
Piper capense, L. f. (*Coccobryon*, Kl.)
Lasiosiphon glaucus, Fres.
Thesium tenuissimum, Hook. f.
Thonningia sanguinea, Vahl.
Euphorbia ampla, Hook. f.
Phyllanthus sp. (fragment)
Pilea quadrifolia, A. Rich.
Parietaria mauritanica, L. var.
Calanthe corymbosa, Lindl. ? (our type is not so much advanced; it is hardly comparable)
'*Angræcum arcuatum*, Lindl.' (of Sir J. Hooker's Enumeration of Mann's plants).

Polystachya elegans, Reichb. f.
,, =Mann, 1339.
Disa alpina, Hook, f.
Holothrix (*Peristylus tridentatus*, Hook, f.).
Habenaria attenuata, Hook. f.
,, *microceras*, Hook. f. ? (type in fruit)
,, *Mannii*, Hook. f.
,, sp. (not identified)
Renealmia africana, Bth. ? in fruit.
Hypoxis villosa, L., var. *recurva*.
Hesperantha alpina, Bth. (*Geissorhiza*, Hook. f.)
Romulea camerooniana, Baker.
Commelina sp. nov. ? but required with ripe capsules.
Cyanotis Mannii, C. B. Clarke.
Luzula campestris, L. var.
Scirpus atrosanguineus, Bkler. (*Isolepis schœnoides* of Hook. f.; Enumeration of Mann's Cameroons plants)
Cyperus, apparently young state of Mann's 1358, *sub nom. C. ingrata*, Kth.
Kyllingia cylindrica, Nees.
Oplismenus africanus, Beauv.
'*Pennisetum riparioides*, Hochst. ?' of Mann's Enumeration.
Trisetum (*Aira pictigluma*, Steud.).
Avena Neesii, Hook. f.

II. Cryptogams.

Cyathea Manniana, Hook.
Hymenophyllum ciliatum, Sw.
Trichomanes radicans, Sw.
Cheilanthes farinosa, Kaulf.
Pteris aquilina, L.
,, *quadriaurita*, Retz.
,, ,, var. *ludens*, Beddome.
,, *brevisora*, Baker.
Asplenium lunulatum, Sw.
,, *furcatum*, Thunb.
,, *brachypteron*, Kunze.
,, *cicutarium*, Sw.
,, *anisophyllum*, Kunze (high mountain form).
,, *Thunbergii*, Kunze.
,, *serra*, Langsd. and Fisch.
,, *protensum*, Schrad.
,, *Filix fœmina*, Bernh.
Didymochlæna lunulata, Desv.
Aspidium angulare, Sw.
Nephrodium Filix mas, Rich., var. *N. elongatum*, H. and G.
,, *cicutarium*, Baker.
,, sp. near *Spekei*, Baker ? (too incomplete)
,, *punctulatum*, Baker.
Nephrolepis cordifolia, Presl.
Gymnogramme javanica, Blume.
Acrostichum spathulatum, Bory.
Acrostichum sorbifolium, L. ? (too imperfect)

Polypodium lineare, Thunb.
Marattia fraxinea, Sm.
Lycopodium fertile, Baker.
" *dacrydioides*, Baker.
Selaginella Vogelii, Spring.
Usnea barbata, f. *florida*, Fr.
Stereocaulon, sp. probably *ramulosum*, Ach.
Neckera pennata, Hedw.
Bryum Commersonii, Brid.
Meteorium imbricatum (Schw.).
Leptodontium pungens, Mitt.
Plagiochila dichotoma, Nees.
Metzgeria myriapoda, Lindbg.

Report of the Committee, consisting of Professor RAY LANKESTER, Mr. P. L. SCLATER, Professor M. FOSTER, Mr. A. SEDGWICK, Professor A. M. MARSHALL, Professor A. C. HADDON, Professor MOSELEY, *and* Mr. PERCY SLADEN (*Secretary*), *appointed for the purpose of arranging for the occupation of a Table at the Zoological Station at Naples.*

YOUR Committee report that the table at their disposal has been fully occupied during the past year, and they beg to direct attention to the subjoined reports of the naturalists to whom it has been granted as evidence of satisfactory work done, which probably could not have been undertaken elsewhere with equal success.

The general efficiency and good organisation of the Zoological Station at Naples is too well known to need recapitulation. The institution continues in its course of steady development, and its sphere of action will shortly be still further extended by the opening of the physiological laboratory. The new building, which is now rapidly approaching completion, is expected to be in working order before the close of the year. This addition will probably greatly increase the number of workers at the Station, in consequence of the exceptional facilities that physiological students will there find for carrying out a systematic course of experiments.

It may be of general interest to state that the Zoological Station has recently carried out, at the instigation of the Italian Ministry of Agriculture and Commerce, a number of investigations of a practical bearing on the fishery industry. One of the most important in a commercial point of view has reference to the question of trawl-fishing. Trawl-fishing, as is well known, has been alleged to be hurtful to the propagation of food-fishes, by destroying the eggs, which are deposited on the sea-bottom. This question has been made the subject of careful research by the Station; and the results arrived at may be briefly summarised in the statement that positive evidence has been procured that thirty-five species of food-fishes, which include those most important in a commercial point of view, produce pelagic or floating eggs; and that consequently the supposed injurious effect of trawl-fishing is, in the case of these forms, proved to be an illusion; and that legislative restriction of trawl-fishing, based on these reasons, can safely be abandoned. The Italian Ministry

has fully recognised the importance of these researches, which will be published *in extenso* before the end of the year.

Some time ago the Italian Government made arrangements with the Station for the instruction of naval officers in the proper modes of collecting and preserving marine organisms, and it will be remembered that several important collections have been made by officers thus qualified. The Russian navy has now adopted the same course, and has just concluded a special contract with the Station for the instruction of officers belonging to that service. The important scientific gains which are likely to accrue to any country whose officers are thus practically acquainted with the technical methods of preserving animals for histological investigation are too obvious to need exposition.

The British Association Table.—Two naturalists have occupied the British Association Table during the past year. Hitherto the table has been occupied only by zoologists; but your Committee have this year the pleasure to report a deviation from this custom, the use of the table having been granted to a botanist—Mr. John Gardiner, late Scientific Adviser to the Board of Agriculture of the Bahamas. As Mr. Gardiner travelled from the West Indies for the purpose of carrying out certain special investigations at Naples, permission was given to him by your Committee to hold the table for the period of twelve months—the current year. Mr. Gardiner's intermediate report, which is annexed, will fully justify the expediency of granting the table for this extended term, and will also bear testimony to the interesting results which are likely to reward Mr. Gardiner's further labours if he is permitted to complete his term of occupancy. Your Committee would also venture to direct attention to Mr. Gardiner's remarks on the Zoological Station in general, and on the claim which the British Association Table has for continued support.

The use of a table was also granted to the Rev. Canon A. M. Norman. This your Committee were able to do by the favour of Prof. Dohrn, who with great kindness placed at their disposal a second table in consideration of the fact that in previous years the British Association Table had for some months remained unoccupied. Dr. Norman worked at Naples for five weeks and has furnished a report, which is annexed.

Two other applications for the British Association Table were received by the Committee during the past year, which the Committee were unable to grant.

For the next year a preliminary inquiry for permission to use the table has already been made by an able naturalist, who wishes to commence work in January. As Mr. Gardiner's term of occupancy will not terminate until December, if the lease of the table is renewed, this would ensure a continuance of occupation.

With these facts before them and the satisfactory character of the present report, your Committee feel justified in expressing the hope that the Council will renew the grant (100*l.*) for the ensuing year.

The Publications of the Station.—The progress of the various works undertaken by the Station is here summarised:—

(1) Of the 'Fauna und Flora des Golfes von Neapel' the following monograph has been published since the last Report:—XIV. J. Fraipont, 'Polygordius.'

The following works are in the press, and will probably be published in 1887:—H. Eisig, 'Capitellidæ,' and G. von Koch, 'Gorgoniidæ.'

(2) Of the 'Mittheilungen aus der Zoologischen Station zu Neapel' vol. vii. part ii. has been published.

(3) Of the 'Zoologischer Jahresbericht' for 1885 Parts II. and III. are published. The remainder will be out shortly.

Extracts from the General Report of the Zoological Station.—The officers of the Station have courteously furnished lists (1) of the naturalists who have occupied tables since the last report, (2) of the works published during 1886 by naturalists who have worked at the Zoological Station, (3) of the specimens sent out by the Station during the past year. These details show an increase in the number of naturalists who have worked at the Station, and in the total value of the specimens distributed, as compared with the previous year.

I. *Report on the Occupation of the Table, by* Mr. John Gardiner.

The Committee of the British Association having kindly granted me the use of their table at the Naples Zoological Station for the year 1887, I arrived at Naples on February 1. For the first two months my work was much hindered, partly by frequent indisposition, due to the very inclement weather, partly by delay in the arrival of my microscope, &c. During this time I occupied myself mainly in familiarising myself with the algal flora of the gulf, in which work I was much aided by the herbarium made by Dr. G. Berthold, and by Sig. Lo Bianco, the conservator of the Station.

The first research I made was suggested to me by a fellow botanist at the Station, who pointed out to me the surprising statements made by Berthold in his monograph on the *Bangiaceæ*, as to their resistance to drying and to the action of various reagents. I thought the statements were worth testing, and accordingly repeated Berthold's experiments, with others of my own, upon *Bangia fusco-purpurea* and *Porphyra leucosticta*. My results, except with regard to drying, are entirely at variance with Berthold's. He says that in fibres of *Bangia* kept in concentrated glycerine for several months many cells still remained alive, and considers it probable that the cells in some preparations made three years before were still alive. I made experiments with thoroughly dried material, and with material from which only the superfluous moisture had been removed, immersing it in concentrated glycerine in a watch-glass. In various periods, from a few minutes to an hour, the fibres assumed a bright reddish-brown colour when seen against a black surface, and under the microscope all the cells were found to be much contracted, and reddish-brown by reflected, green by transmitted, light. On washing and returning to sea-water no change was visible, even after several days. The same reddish-brown colour is seen when the plant dies after being kept for some time in sea-water. On immersing fresh fibres for a minute or a little more in glycerine, washing and returning to sea-water, most of the cells were, as a rule, found to have resisted the glycerine and to be still alive. In one case young fibres resisted it for half-an-hour. I conclude from these experiments that while *Bangia* does resist the action of concentrated glycerine, such resistance is very limited in its duration.

Alcohol of 30, 50, and 70 per cent. kills at once, producing the reddish-brown colour and contraction of the cells. In 90 per cent. alcohol the cells contracted greatly, but retained their green colour both by reflected and transmitted light, the contents being granular; on carefully drying and returning to sea-water, the cells swelled again, but the con-

tents became homogeneous, and after keeping in sea-water for some days showed no sign of life. Berthold states that in *Bangia* kept for several days in absolute alcohol, and then brought into sea-water, many cells showed the same appearance as in the living plant, while others were completely killed and decolourised. I took great care in this experiment to avoid diluting the alcohol by any moisture in the fibres, and my results were curious. The fibres shrivelled up, cells contracted, and contents became homogeneous, but the green colour remained, except at the torn end of a fibre, where six or seven cells lost their chlorophyll, and showed the red colour. Even when specimens were kept in alcohol for a week, the green colour remained in many cells; sometimes cells towards the middle of a fibre were decolourised, while those on both sides remained green. In no case did the cells resume their normal appearance after being carefully freed from alcohol by drying and returned to sea-water.

In nature *Bangia* lives on the rocks above high-water mark, dashed by the spray. This may explain the curious fact that I was able to keep it alive in freshwater for eight days, while it died in four or five days when kept in sea-water. In nature it is often exposed to heavy rain, sometimes almost continuously for some days, and this probably accounts for its resistance. I believe that if, instead of keeping the plant immersed in water, it were simply kept moist by a spray of fresh water, it would remain alive for a still longer time, though not so long as if moistened by a spray of sea-water. Its quick death in sea-water I take to be due to its immersion.

The ordinary reagents used for killing—osmic acid, picric acid, sublimate, iodine—killed *Bangia* very quickly, producing considerable changes in its appearance.

Porphyra leucosticta showed similar phenomena, but its resistance is considerably less than that of *Bangia.* It dies very quickly in fresh water.

The resistance of *Bangia* to reagents appears to be due mainly to the cuticle which surrounds the fibres, which is insoluble in sulphuric acid. *Porphyra* appears not to possess such a cuticle. Very young plants of *Porphyra*, however, resisted glycerine for nearly an hour, the cells gradually, from the base to the tip, becoming disorganised.

The hypha-like prolongations of the basal cells of *Bangia* which form the rhizoids, as a rule, pass down inside the tube to the base; occasionally, however, lateral roots are found; and when this is the case the rhizoid, surrounded by a thick membrane, pushes its way through the cell wall and cuticle in a manner analogous to that of the roots of higher plants.

Bangiaceæ are not available in summer here; in autumn and winter I hope to do further work at them.

I did a considerable amount of work on *Acetabularia mediterranea*, following up its development from the state of a simple unbranched thallus to the final development of the pileus. The memoirs of De Bary and Strasbürger, and of Woronin are not in the library; consequently when at last I saw them I found that most of my results had already been described. But I found a few things which I take to be new. The branched hairs, which in the young stage are in whorls round the stem, and in older stages form a tuft in the centre of the pileus, are usually described and drawn as consisting of distinct cells. I find, on the contrary, that the cavities of the branches always during life remain in communication with one another

and with that of the main stem; the branches are developed as hollow processes of the mother cell, and these constrictions are formed by thickening of the cell-wall at the points branching, but the lumen does not close during life, though it is reduced to a very narrow opening. When the stem of a vigorous plant is cut, the contents flow out of the opening, and the protoplasm contained in the basal branches of the hairs can be observed to flow into the stem, while in the smaller hairs the contents, so to speak, endeavour to do so, collecting at the base of the branch, but not being able to pass through on account of the constriction. When the hairs die off, the smaller hairs die first, the contents apparently passing down into the cell below, and a membrane being formed across the opening, and so on down to the basal cell. I have only *observed* this in the case of the basal cells, but I conclude that it applies to the others, for the basal cells at this time are crammed full of protoplasm and other cell-contents, so that they are almost opaque, while their minor branches have disappeared. The membrane formed across the opening into the stem is thin at first, but becomes thicker by the deposit of layers of cellulose. The hairs appear to be analogous to the branches of the West Indian *Rhipocephalus* and *Corallocephalus*. Their function I could not determine; they contain a small amount of chlorophyll and the red oil found in the chlorophyll bodies, but too little to be of much use, except perhaps in the basal branches. Perhaps they are reduced organs; it is conceivable that at one time they may have been important organs of assimilation, as the branches of the West Indian forms mentioned are still, and that their function may have been taken from them by the greater development of the pileus.

I also investigated the mode of formation of the pileus. The cell-wall at the end of the stem is very thick just before it begins to be formed. The inner layers of cellulose appear to be absorbed at definite points, while the outer ones are pushed out, the cell being intensely turgid at this time, and form the walls of the branches. There is no organic connection between the branches; at their bases they are distinct, and when decalcified the branches can be readily separated from one another; in the slightly calcified *A. crenulata* of the West Indies they are often separate during life. The branches of the pileus would appear to be more or less homologous with the hairs.

I also made some experiments on the brown ethereal oil found in the chlorophyll bodies of the majority of young *Acetabularia*, which it colours a rich red brown, and even in many full-blown ones. I could find no starch in the brown specimens, while there was a good deal in the green ones, and I thought it possible that the oil might be a product of assimilation, especially as some species of *Vaucheria*, *Musa*, and other plants are said to contain oil instead of starch. My experiments gave no result, positive or negative; partly, at any rate, owing to the difficulty of keeping *Acetabularia* alive in an aquarium. There seems, however, to be a presumption in favour of the theory that the oil is a product of assimilation.

I hope, in the autumn, to be able to make some observations on the sinking of the cell-contents into the basal part of the stem, the death of the upper parts, and the condition of the plant during the winter.

One of the main objects of my coming to Naples was the study of the *Siphoneæ*, and especially *Caulerpa*. I have studied in addition to *Acetabularia* and *Caulerpa*, the genera *Codium*, *Valonia*, *Udotea*, *Bryopsis*, and *Dasycladus*. My results with *Caulerpa* are perhaps worth stating, though they are by no means complete. As a means of inducing the plant to

produce spores, I starved it by depriving it almost entirely of light, and after a while by aërating the water only at intervals. As a result, after some weeks, long (4 to 6 cm.), thin (·5 to ·75 mm.), cylindrical processes, pointed at the end, grew out from the rhizome and leaves, pointing perpendicularly upwards to a hole in the top of the box, through which a little light came. These processes and the rhizome were very dark green in colour, almost black, but usually white at the tips, while some were dark green the whole length. When put into fresh sea-water those with white tips burst at the tips, emitting a little cloud. On examining this, it appeared to consist of protoplasm and chlorophyll bodies; but the latter were in very active oscillating motion, even when apparently quite freed from the protoplasm. The motion differed from ordinary molecular motion of particles in a fluid, in that there was very marked change of relative position. It continued for some hours, when a damp chamber was used. The bodies were of oval form, and in various stages of formation; groups of two, four, eight, and large balls of them, apparently consisting of thirty or forty, were seen. I would have thought the balls due to the contact of the protoplasm with the water, but I have since seen them in the interior of processes preserved, stained, and cut with the microtome. It appeared as if I had found the long-sought zoospores of *Caulerpa*, and I cannot yet decide whether they were chlorophyll bodies or zoospores. In specimens kept in a damp chamber I observed bodies of different sizes, the larger having more active motion than the smaller. I watched one large one sailing about through the drop, and saw it come in contact with a smaller one which was oscillating quietly. They coquetted with each other for some minutes, and then appeared to become united in some way, oscillated together for a while, and then stopped. I kept them under observation for three days, but no further change took place, and the rapid growth of bacteria in the drop appeared to kill them. Iodine killed these bodies, stopped their motion, and rendered evident what I took to be two cilia, but which may have been simply particles of protoplasm. I have made many experiments, and have seen several apparent instances of conjugation like the above, but have not been able to obtain further development. The chlorophyll bodies of normal *Caulerpa* move so long as any currents continue, but when these are prevented stop at once. The processes, which were dark green throughout, and the rhizome did not burst in a change of water, and when cut no protoplasm flowed out. Their contents consisted of a dense mass of these chlorophyll bodies, or zoospores, which showed the same movements when pressed out into water. Later I found that a specimen of *Caulerpa* which had been kept in an ordinary tank in ordinary light had produced a number of processes of a similar kind, some of which burst spontaneously, with the same results as noted above. Others became detached from the parent, developed rhizoids at the previously attached end, flattened out to a leaf-like form, and are growing well: these were branched considerably before becoming detached. Some *Caulerpa* brought to me in the beginning of May from the usual locality, the Magellina, showed profuse proliferation, the young leaves arising from a narrow base and gradually expanding and branching dichotomously, the branches also being flattened; some of this material which I have kept has continued branching, until at present a leaf about 9 cm. long has some 250 branches, up to the tenth order. The branches produced in the aquarium are mostly long, thin, and cylindrical. The material I have been receiving for some time past shows only the ordinary

proliferation. It might appear, therefore, that the 'processes' of which I have spoken merely indicated an occasional special mode of proliferation, and that my 'zoospores' were no zoospores, the later conclusion being *à priori* possible, on account of my want of experience in these matters. But I am quite positive about my observations on the apparent conjugation, and my lurking conviction that the moving green bodies will turn out to be really zoospores is strengthened by the fact that I am told by the authorities here that a botanist who had formerly studied here had seen the zoospores of *Caulerpa* but had not been able to work at them. I trust to make some decisive observations in the great breeding period for many algæ which is approaching.

At present, while keeping an eye on *Caulerpa*, I am working mainly at the reproduction and development of *Sargassum.* My observations are as yet too incomplete for me to give a connected account of them. I have not seen the discharge of the antherozoids nor the process of fertilisation, though I have followed the development of the antherozoids and of the oospore. I have also succeeded in obtaining a tolerably complete series of embryos, including nearly all the early stages in the division of the egg. The difficulty in the earliest stages is to determine what is normal and what is abnormal (owing to artificial conditions) division ; I have some embryos with the same number of cells, having these cells arranged in quite different ways. I hope, however, to conquer this difficulty and to be able to present a complete account of the development of *Sargassum* at the meeting of the Association in 1888. So far as I can see at present, the development is much like that of *Cystosira.* I am also collecting material for a study of the development of the conceptacles in *Sargassum.*

As yet I have not published, or prepared for publication, any of my work, because I consider that I serve my own ends and those of the Association in appointing me to this table better by devoting all my working time while at Naples to the actual business of research and of collecting material for future work.

I have to thank the staff and my fellow-workers at the Station for much valuable information as to methods of preservation, staining, &c., in use among zoologists, which I thought might be serviceable in botany also. I have devoted a good deal of time to the study of these methods, and hope to publish an account of my conclusions when I leave the Station, if not before.

Besides completing my work on the plants already mentioned, I hope to be able to make some researches into the algæ growing in the hot mineral springs of Ischia, and into the algal flora of Lake Avernus ; and I expect to find much to observe in the autumn when many algæ reproduce very actively.

Before concluding, may I be permitted to call the attention of the Committee to the great claims which the Station has upon the support of scientific men in England as well as on the Continent ? I would speak with special reference to England, because England, though second to no Continental country in the amount and value of the biological work she produces, has only two tables at the Station, and even these two she shows some inclination to give up. The advantages which the Station offers to the student, whether he be zoologist, botanist, or physiologist, are these : the best arranged marine laboratory in Europe ; a staff of distinguished men at the head of it, ever ready and willing to assist the student

in every way, but never interfering with his methods or theories until asked for advice, while all the time interesting themselves in the work of each individual; a perfectly disciplined staff of servants and fishermen, trained by the experience of years to supply all one's wants at the shortest notice and to the fullest extent; and a large library, excellent, so far as zoology is concerned, if rather weak in botanical works. It may be said, I believe it *is* said, 'we have zoological stations in England and Scotland: why spend money on a Station established by foreigners in a foreign country?' The answer is that it will be many years before the British Stations can possibly attain to the perfection of the Naples one, if they ever do; directors and servants must acquire that experience in the working details on which so largely depends the value of such a Station; a library must be gradually formed; and in the meantime what are Englishmen, who require to study in a well-appointed laboratory, to do? When we have as good, or nearly as good, a laboratory as the Naples one, by all means let us give up our tables at Naples and spend the money on our own Stations; but till then let us retain our privilege of sending men to study at a laboratory whose at present unrivalled advantages we rather grudgingly, other nations more willingly and generously, admit. We ought to have enough biologists in England to keep our Naples tables filled, and yet have many to attend to the development and improvement of our own Stations. Furthermore, the tropical luxuriance of the Mediterranean fauna and flora must always be an inducement to many Englishmen to study at Naples as well as in their own country.

I may have expressed myself rather strongly, but my reasons for doing so are partly a feeling of injured national pride that England should have only two tables and grudge the money for them, while Germany willingly pays for about a dozen, and Italy, which Englishmen are wont to regard as hardly more than semi-civilised, for about half that number; but mainly a vivid sense of the advantages I myself have derived from my stay here. And if a botanist derives so much good, much more must a zoologist, for the botanist has to contend with the disadvantage of a not very good library, and the want of an assistant, and the zoologist has not. In this connection I would remark that it is the fault of botanists themselves that the library is not better. If more of them came, the library, by the help of their suggestions, would soon improve. At present there is no botanical assistant, for the same reason. I fancy that botanists generally do not know that they are admitted willingly, even desired, at this so-called Zoological Station. And they do not know, I think, of the perfect freedom they would have in their work. While occupying a table here, a man may work at the phanerogamic flora of the district, or at freshwater algæ, or marine algæ, or all of them. There is absolutely no restriction placed upon him. It is much to be desired that more botanists should come to the Station, though a fair number of Germans have been here, including two during part of this year. I believe I am the first Englishman who has studied botanical questions at the Station, but I hope I shall by no means be the last.

In concluding this first report on my occupancy of the table of the British Association, I wish to express my gratitude to the Committee for nominating me, and for so long a period. I also wish to thank Professor Dohrn, Dr. Eisig, Signor Lo Bianco, and the rest of the staff of the Station for the constant courtesy and kindness I have experienced at their hands, and for the help they have in many ways given me.

II. *Report on the Occupation of the Table, by the* Rev. Dr. Norman.

It had long been my desire to pay a visit to the Zoological Station at Naples, and during the past spring an opportunity having presented itself, five weeks in the months of March and April were spent there. The British Association Table was at this time occupied, but on the application of your Committee Dr. Dohrn placed a second table at my disposal. I should be most ungrateful if I did not testify to the great kindness and attention which I received from the whole staff of the Station during my most pleasant and profitable stay at Naples. The management of the establishment seems to have been brought to perfection. The admirable tone, good nature, and courtesy which pervade the entire staff; the smooth, quiet, and efficient working of the establishment —these, combined with the extreme richness of the sea around Naples in representatives of almost every section of marine animals, and pre-eminently of the surface fauna, the calmness of the Mediterranean waters which renders dredging at almost all times practicable, form a combination of essentials to the success of a Zoological Station which perhaps can never be equalled and certainly not excelled elsewhere. Pleasure was anticipated from my visit, but my anticipations were much more than realised.

My object in visiting the Station was, *first*, to see in life certain groups of animals which are unknown in North European seas; *secondly*, to take a general review of the fauna as compared with that of the North Atlantic; and, *lastly*, to study more especially, so far as the very limited time at my disposal would allow, certain groups of the great class Crustacea, which had not been worked out by South European carcinologists. I had in view such orders as the Mysidea, Cumacea, Ostracoda, &c.; but after a few days I was surprised to find how much remained to be done in every order of the Crustacea. Dr. Dohrn kindly placed at my disposal from the museum unexamined material of several groups which it seemed well to study; while the fishermen daily supplied me with far more animals than it was possible to work out. Time sufficed for little more than the collecting, roughly examining, and preserving for more close investigation hereafter the things of interest which passed through my hands. Since my return my time has been so fully occupied with other matters that there has not been opportunity so much as to open the bottles which contain the product of the trip. This report, however, is of course not supposed to be exhaustive. In almost every section of the Crustacea,—Brachyura, Anomura, Macrura, Mysidea, Isopoda, Amphipoda, Ostracoda, Copepoda, and Cirripedia—forms were detected either altogether new or interesting as not hitherto recognised in the Mediterranean at large or at Naples in particular. Even among the Brachyura results were important. An *Inachus*, very abundant in the bay close to the Station, and often taken in company with *I. dorsettensis*, though nearly related to, is manifestly distinct from, the latter species, and is either still undescribed or possibly the *I. mauritanicus* of Lucas, which authors have synonymised with *dorsettensis*. From the deep water were two species, which have recently been figured by Milne-Edwards from the 'Travailleur' Expedition, *Ergasticus Clouei*, Milne-Edwards, and *Heterocrypta Marionis*, Milne-Edwards; together with a

third fine form which appears to be altogether new and belonging to a genus allied to the last. The *Ergasticus*, I may mention, was also taken by the 'Porcupine' Expedition off the Spanish coast; and of the *Heterocrypta* I possess specimens given me previously by the Marquis de Folin, which were taken by the 'Travailleur' Expedition in the Fosse de Cap Breton.

With this brief review of the more interesting Brachyura, I must pass by the remaining groups and only notice one remarkable crustacean of excessive interest. My friend, Professor Sars, to whom I sent a specimen, writes to me on it: 'The interesting parasite detected by you at Naples is certainly a highly remarkable and perplexing form, and the discovery of this animal would alone, I believe, fully recompense your voyage to Italy.'

In 1882 a memoir on an extraordinary parasitic crustacean discovered by Professor Lacaze-Duthiers was published by the Institut de France, illustrated with eight quarto plates.

The parasite thus described, *Laura Gerardiæ*, Lacaze-Duthiers, lives in one of the Antipatharian Actinozoa, which was made the type of a genus by Lacaze-Duthiers, *Gerardia Lamarcki*, Haime; and that author regarded the parasite found by him as an aberrant member of the Cirripedia, and constituted a new section to receive it, named *Ascothoracida.*

It is to this genus that the form now discovered appears to have closer relationship than to any other. The Neapolitan parasite, for which I propose the name *Synagoga*[1] *mira*, is also a parasite on an Antipatharian, *Antipathes larix*, Ellis, but while *Laura* is buried beneath the tissues of the host, being completely covered, except in one minute spot by the sarcosome of *Gerardia*, *Synagoga* is an external parasite attached to the surface of the *Antipathes.* At first sight the latter looks very unlike the former, and, with the naked eye might easily be mistaken for one of the Cypridinidæ, inasmuch as the body of the animal is covered by two nearly circular valves; these valves ('carapace,' Lacaze-Duthiers) are in *Laura* of enormous size and three times the length of the body, but in *Synagoga* they are shorter than the body. In *Laura* the antennæ are weak, feeble structures; here they are strongly developed grasping organs; the mouth organs in both cases are formed for piercing and sucking, and follow the same type. In both genera the adductor muscle which passes through the body into the valves is similar; and in both, as in the Ostracoda, the organs of reproduction are extended on either side into and beneath the valves. Both genera are furnished with six pairs of limbs posterior to the oval members and a caudal bifurcation; but while in *Laura* these members are simple, apparently unjointed, and somewhat rudimentary, in *Synagoga* they are two branded, jointed, and freely setose, and the laminæ of the caudal furca are much longer, spined on the edges, and provided with long setæ. It will thus be obvious that *Synagoga* is a type of much less retrograde character than *Laura*. Upon its relations I will only say at present that while, on the one hand, there is much in its structure which reminds us of the Cypris-condition of a larval Cirriped, there are also features which recall strongly to us the much disputed genus *Nebalia.*

[1] Συναγωγή, a meeting-spot.

III. *A List of Naturalists who have worked at the Station from the end of June* 1886 *to the end of June* 1887.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
359	Dr. P. de Vescovi	Italy	Aug. 1, 1886	Sept. 7, 1886
360	Dr. G. Rovelli	"	" 1, "	" 7, "
361	Prof. F. Gasco	"	" 1, "	Oct. 19, "
362	Dr. D. Carazzi	"	" 12, "	" 1, "
363	Prof. S. Trinchese	"	" 12, "	Dec. 31, "
364	Dr. C. Crety	"	" 14, "	" 31, "
365	Prof. C. Emery	"	" 19, "	Oct. 19, "
366	Prof. C. Chun	Berlin Academy	" 25, "	" 17, "
367	Dr. K. Brandt	" "	Oct. 5, "	Mar. 1, 1887
368	Dr. J. M. Janse	Holland	" 22, "	Jan. 15, "
369	Mr. G. Bidder	Cambridge	" 24, "	June 29, "
370	Dr. E. Fraas	Würtemberg	Nov. 8, "	Dec. 31, 1886
371	Dr. S. Apáthy	Hungary	" 8, "	—
372	Mr. H. Bury	Cambridge	" 10, "	May 29, 1887
373	Lieutenant Saxe	Russian Navy	" 11, "	" 8, "
374	Dr. F. Noll	Baden	" 12, "	April 6, "
375	Dr. G. Jatta	Italy	Jan. 1, 1887	June 25, "
376	Dr. J. Raffaele	"	" 1, "	—
377	Prof. S. Trinchese	"	" 1, "	—
378	Dr. F. S. Balsamo	Province of Naples	" 1, "	—
379	Dr. F. S. Monticelli	" "	" 1, "	—
380	Prof. A. G. de Linares	Spain	" 14, "	June 12, 1887
381	Mr. J. Gardiner	British Association	Feb. 2, "	—
382	Dr. Fleischmann	Bavaria	" 15, "	May 1, 1887
383	Mr. E. Penard	Switzerland	" 18, "	" 12, "
384	Dr. P. Pelseneer	Belgium	" 21, "	June 23, "
385	Prof. J. Steiner	Berlin Academy	" 24, "	April 8, "
386	Dr. von Schröder	Strasburg	Mar. 1, "	May 1, "
387	Sr. Madrid Moreno	Spain	" 1, "	" 15, "
388	Dr. A. Fischer	Saxony	" 7, "	Apr. 22, "
389	Dr. J. W. van Wijhe	Holland	" 17, "	—
390	Dr. G. Motti	Italy	" 25, "	—
391	Stud. Med. Marcuse	Prussia	" 25, "	June 23, "
392	Prof. C. Rabl	Zoological Station	" 26, "	Apr. 20, "
393	Rev. Dr. A. M. Norman	British Association	" 28, "	May 1, "
394	Dr. von Davidoff	Bavaria	" 29, "	Apr. 13, "
395	Dr. A. Korotneff	Russia	Apr. 17, "	May 15, "
396	Dr. Reichenbach	Zoological Station	" 22, "	" 19, "
397	Dr. B. Rawitz	Prussia	May 16, "	—
398	Prof. A. della Valle	Italy	June 23, "	—
399	Prof. Repiachoff	Russia	" 24, "	—

IV. *A List of Papers which have been published in the year* 1886 *by the Naturalists who have occupied Tables at the Zoological Station.*

Dr. J. Frenzel . . Mikrographie der Mitteldarmdrüse der Mollusken. I. Theil, 'Nova Acta K. Leop. Carol. Akad. der Naturforscher,' Bd. xlviii. Halle, 1886.

Prof. E. Metschnikoff . Embryologische Studien an Medusen. Wien, 1886.

Prof. J. Steiner . . Ueber das Centralnervensystem des Haifisches und des Amphioxus lanceolatus, und über die halbcirkelförmigen Canäle des Haifisches. 'Sitz.-Ber. K. Pr. Akad. Wissensch., Berlin.' Bd. xxviii. 1886.

Prof. J. Steiner . .	Functioneller Beweis für die Richtigkeit der morpholog. Ansicht von der Entstehung des asymmetrischen Baues der Pleuronectiden. Heidelberg, Festschrift, 1886, p. 127.
Dr. W. J. Vigelius . .	Zur Ontogenie der marinen Bryozoen. 'Mitth. Zool. Station,' Bd. vi. 1886.
Dr. W. Patten . .	Eyes of Molluscs and Arthropods. *Ibid.*
Dr. E. von Daday . .	Ein kleiner Beitrag zur Kenntniss der Infusorien-Fauna des Golfs von Neapel. *Ibid.*
Dr. W. Repiachoff . .	Zur Anatomie u. Entwickelung von Discophilus gyrociliatus. 'Verh. Neuruss. Nat. Ges. Odessa,' 1886.
Dr. J. Walther und P. Schirlitz	Studien zur Geologie des Golfs von Neapel. 'Zeitschr. Deutsch. Geol. Gesellschaft,' Jahrg. 1886.
Prof. C. Chun . .	Ueber Bau u. Entwickelung der Siphonophoren. Dritte Mitthlg. 'Sitz.-Ber. K. Pr. Akad. Wiss. Berlin,' Bd. xxxviii. 1886.
Prof. G. von Koch . .	Untersuch. über das Wachsthum von Antipathes. 'Festschr. der technischen Hochschule Darmstadt,' 1886.
Dr. F. Raffaele . .	Papille ed organi di senso cutanei nei Pleuronettidi del genere Solea. Estr. 'Rivista Ital. Sc. Nat. pubbl. dal Circolo degli aspiranti Naturalisti,' Napoli, Anno II. 1886.
Dr. J. H. Wakker . .	Die Neubildungen an abgeschnittenen Blättern von Caulerpa prolifera. 'Verslagen en Medeelingen Kon. Akad. van Wetenschap. Afd. Naturk,' 3de Reeks, Deel II. 1886.
Prof. G. Colasanti . .	Il Pigmento blu delle Idromeduse. Estr. 'Atti. R. Accad. medica di Roma,' (2) vol. xii. 1886.
Dr. E. Rohde . . .	Histol. Untersuchungen über das Nervensystem der Chætopoden. 'Sitz.-Ber. K. Pr. Akad. Wissensch. Berlin,' Bd. xxxix. 1886.
Prof. W. Krause . .	Die Nervenendigung im elektr. Organ. 'Internationale Monatsschrift,' Bd. iii. 1886.
" . .	Ueber die Folgen der Resection der elektrischen Nerven des Zitterrochen. 'Sitz.-Ber. K. Pr. Akad. Wissensch. Berlin,' Bd. xxxviii. 1886.
Dr. C. Hartlaub . .	Ueber den Bau der Eleutheria. 'Zool. Anzeiger,' 1886.
Prof. C. Emery . .	La Régénération des Segments Postérieurs du Corps. 'Arch. Ital. de Biologie,' t. vii. 1886.
Dr. F. Albert . . .	Ueber die Fortpflanzung von Haplosyllis spongicola, Grube. 'Mitth. Zool. Station Neapel,' Bd. vii. 1886.
Prof. W. Preyer . .	Ueber die Bewegungen der Seesterne. I. Hälfte. *Ibid.*
Dr. A. Onodi . . .	Neurologische Untersuchungen an Selachiern. 'Internat. Monatsschrift f. Anatomie u. Histologie,' Bd. iii. 1886.
Cand. K. Wenkebach .	Beiträge zur Entw. Geschichte der Knochenfische. 'Arch. Mikr. Anat.' Bd. xxviii. 1886.
Cand. J. L. Dobberke .	Verslag der Onderzoekingen, verricht aan de Nederlandsche Tafel in het Zoölogisch Station, etc. 'Nederland. Staatscorr.' 1886.

V. *A List of Naturalists to whom Specimens have been sent from the end of June* 1886 *to the end of June* 1887.

					Lire c.
1886.	July	4	Mr. E. Marie, Paris . . .	Various	83·05
	"	5	Mr. Weber-Sulzer, Winterthur .	Corallium, Isis . .	37·45
	"	7	Conte Peracca, Turin . .	Elaphis	25·
	"	"	Mr. A. Blume, Iver . . .	Collection	122·
	"	12	Dr. Kerbert, Aquarium, Amsterdam	Living Muræna . .	25·
	"	13	Mr. J. Tempère, Paris . .	Various	15·10
	"	"	Dr. A. Andres, Milan . .	Actinia	7·70
	"	14	Prof. Ussow, Zootom. Cabinet, Kasan	Collection . . .	619·15
		20	Prof. A. C. Haddon, Dublin .	Collection . . .	295·45

					Lire c.
1886.	July	21	Mr. W. Schlüter, Halle-on-Saale	Various . . .	50·
	„	31	Exhibition connected with the Meeting of German Naturalists and Physicians, Berlin .	4 Collections for school purposes . . .	687·50
	Aug.	4	Prof. Stepanoff, Charkov . .	2 Collections . .	208·20
	„	6	Prof. A. Froriep, Tübingen .	Embryos of Torpedo .	51·75
	„	13	Mr. H. M. Gwatkin, Cambridge .	Mollusca . . .	75·
	„	„	Prof. Kollmann, Bâle . .	Embryos of Dogfish .	80·25
	„	22	P. Rousseau and Co., Paris .	Various . . .	16·65
	„	24	Mr. J. Honegger, Zürich . .	Brains of Acanthias, Heptanchus . .	12·40
	„	„	Physiological Institute, Zürich .	Brains of Dogfish .	6·35
	„	28	Dr. Rückert, Munich . . .	Yolk-sacks of Dogfish .	6·70
	Sept.	3	Prof. Krause, Göttingen . .	Embryos of Torpedo .	71·95
	„	10	Morphol. Labor. Cambridge .	Bonellia, Sipunculus, &c.	458·10
	„	15	Prof. Gravis, Liège . . .	Posidonia . . .	34·50
	„	16	Obergymnasium, Tarajevo .	Small Collection . .	82·70
	„	23	Prof. Kollmann, Bâle . .	Embryos of Dogfish .	82·65
	„	27	Dr. Amans, Montpelier . .	Various . . .	26·30
	„	29	Prof. Leuckart, Leipzig . .	Collection . . .	213·95
	Oct.	1	Dr. Barrois, Lille . . .	Palæmonetes . .	3·20
	„	4	Maison de Santé, Schöneberg .	Collection . . .	187·50
	„	5	Dr. A. Corona, Sassari . .	Aplysia . . .	—
	„	6	Owens College, Manchester .	Collection . . .	768·15
	„	„	Mr. H. C. Chadwick, Manchester .	Collection . . .	85·25
	„	7	Società Tecnica, Florence . .	Various . . .	83·50
	„	12	Instituto Tecnico, Naples . .	Collection . . .	311·30
	„	„	Prof. Barrois, Lille . . .	Orchestia . . .	3·
	„	14	Morphol. Labor., Cambridge .	Sepia	252·50
	„	17	Mr. E. Rigby, Blackburn . .	Collection . . .	145·45
	„	„	Mr. C. Jefferys, Tenby . .	Crustacea . . .	294·10
	Nov.	7	Dr. Carazzi, Spezia . . .	Collection . . .	225·
	„	„	Dr. P. Pelseneer, Brussels . .	Tiedemannia . .	6·10
	„	„	Prof. C. Vogt, Geneva . .	Terebratula . . .	11·35
	„	11	Mr. F. S. Oliver, Kew . .	Caulerpa . . .	20·50
	„	„	Dr. Kihlmann, Helsingfors .	Caulerpa . . .	8·
	„	12	Dr. J. Vajela, Klausenburg .	Collection . . .	187·50
	„	15	Prof. A. Carruccio, Museo Zoologico, Rome	Collection . . .	2000·
	„	19	Prof. A. Della Valle, Modena .	Collection . . .	136·35
	„	20	Mr. T. G. Nicholson, London .	Amphioxus . . .	2·50
	„	24	Dr. J. W. van Wijhe, Almelo .	Amphioxus . . .	6·60
	„	„	Rev. Dr. Norman, Burnmoor Rectory	Collection . . .	418·10
	„	26	Prof. Uljanin, University, Warsaw	Collection . . .	579·40
	„	„	University College, London .	Mollusca . . .	261·40
	„	27	Mr. J. Tempère, Paris . .	Various . . .	47·80
	„	29	Mr. W. Schlüter, Halle . .	Collection . . .	130·70
	„	„	Dr. J. Vajela, Klausenburg .	Tapeworms . . .	8·50
	„	„	Dr. O. Hamann, Göttingen .	Brissus . . .	23·05
	Dec.	4	Capt. Dannevig, Flodevig, Norway	Crustacea . . .	37·50
	„	„	Prof. Moseley, Oxford . .	Embryos and Various	153·15
	„	„	Grossh. Museum, Darmstadt .	Octopus . . .	46·25
	„	„	Dr. Amans, Montpelier . .	Dactylopterus . .	25·70
	„	11	Prof. Landois, Greifswald . .	Collection . . .	375·
	„	„	Mr. H. Putze, Hamburg . .	Various . . .	29·55
	„	„	Dr. Rawitz, Berlin . . .	Lima, Pecten, &c. .	19·30
	„	„	Dr. Schuchardt, Görlitz . .	Gelidium . . .	20·50
	„	14	University, Philadelphia . .	Collection . . .	376·70
	„	„	Swarthmore Coll., Swarthmore .	Collection . . .	376·70

					Lire c.
1886.	Dec.	14	Conte Peracca, Turin	Lacerta	13·50
	„	18	Prof. C. Chun, Königsberg	Pelagia	58·15
	„	20	Mr. W. Schlüter, Halle	Various	126·35
	„	„	I. R. Educatorio, Naples	Various	40·70
	„	„	III. „ „	Various	62·25
	„	24	Zootom. Cabinet, St. Petersburg	Collection	384·05
	„	„	Prof. Richiardi, Pisa	Various	147·05
	„	27	Dr. Lahille, Toulouse	Ascidiæ	21·20
	„	30	Morphol. Lab., Cambridge	Various	12·50
1887.	Jan.	6	Prof. Hertwig, Munich	Collection	335·30
	„	6	Prof. Hensen, Kiel	Heads of Fish	31·
	„	6	Dr. E. Fraas, Stuttgart	Echinoderms	43·70
	„	6	Prof. Lankester, London	Amphioxus	6·50
	„	7	Prof. Vogt, Geneva	Pteropoda	11·35
	„	„	Miss Heath, Plymouth	Various	8·15
	„	„	Cav. Brogi, Siena	Various	32·50
	„	10	Prof. A. Lang, Jena	Sepia	23·10
	„	„	Mr. E. Marie, Paris	Torpedo	23·70
	„	11	Prof. Gasco, Rome	Various	192·
	„	15	Dr. O. Hamann, Göttingen	Spatangus	16·45
	„	31	Prof. Wilson, Brynn Mawr Coll.	Collection	825·55
	Feb.	3	Prof. Batelli, Perugia	Various	30·30
	„	6	Mr. O. Fric, Prague	Various	104·95
	„	„	Prof. Rabl, Prague	Oikopleura	4·65
	„	9	Dr. J. W. van Wijhe, Almelo	Embryos of Dogfish	28·70
	„	10	Dr. Carazzi, Spezia	Brains of Dogfish	13·
	„	„	Mr. Th. Wardle, Leek	Living Murex	33·
	„	15	Mr. E. Marie, Paris	Various	33·45
	„	17	Collegium, Szekely Udverhely	Collection	169·35
	„	„	Oberrealschule, Kecskemét	Collection	242·60
	„	„	Mr. G. Maclaine, Lochbine	Various	55·95
	„	18	Zoolog. Museum, Charkoff	Collection	101·80
	„	„	Zoolog. Institute, Charkoff	Collection	42·35
	„	23	Dr. Barrois, Lille	Pinna nobilis	16·
	„	26	Dr. F. Lahille, Toulouse	Actiniæ	24·65
	„	28	Prof. Dames, Berlin	Orthagoriscus	20·
	„	„	University College, London	Various	34·65
	March	4	Dr. Janse, Leyden	Algæ	2·90
	„	8	Mr. J. Krause, Glogau	Various	42·25
	„	„	Prof. Hubrecht, Utrecht	Torpedo, Petromyzon	60·
	„	12	Staatsgymnasium, Munkacs	Collection	125·
	„	„	Società Tecnica, Florence	Various	26·
	„	„	Prof. Giglioli, Florence	Orthagoriscus	84·
	„	„	Mr. G. Maclaine, Lochbine	Various	6·65
	„	„	Dr. Lampert, Stuttgart	Various	9·85
	„	16	Prof. A. M. Marshall, Manchester	Corallium	37·65
	„	„	Prof. Hensen, Kiel	Eyes of Pecten	4·10
	„	18	Prof. Menzbier, Univer. Moscow	Collection	187·35
	„	20	Dr. O. Harmann, Göttingen	Brissus	11·25
	„	„	Labor. d'Anat. Comp., Geneva	Amphioxus	7·85
	„	22	Accademia Navale, Leghorn	Collection	525·30
	„	„	University College, Nottingham	Collection	610·55
	„	28	National Museum, Bùdapest	Siphonophora	182·10
	„	„	Dr. A. Appellöf, Upsala	Sepia	33·80
	„	„	Mr. H. Knorr, Munich	Various	21·20
	„	29	Conte M. Peracca, Turin	Lacerta	9·75
	April	7	Rev. Heinersdorff, Elberfeld	Sepia, Corallium	10·85
	„	11	Mr. P. L. Trico, Trino	Amphioxus	5·
	„	13	Count Rose, Baden-Baden	Collection	100·
	„	„	Geol. Mineral. Inst. Freiburg i/B	Collection	146·15
	„	14	Prof. G. Frizzi, Perugia	Fish	13·25
	„	17	Mr. C. Redlich, Brünn	Various	13·25

				Lire c.
1887. April	17	Prof. S. Lovén, Stockholm	Arbacia	9·70
„	„	Cons. F. Nausen, Bergen, Norway	Amphioxus	21·
„	18	Mr. Weber-Sulzer, Winterthur	Collection	190·45
„	„	Mr. G. Schneider, Bâle	Various	67·75
„	„	Dr. A. Kaufmann, St. Gall	Physophora	21·40
„	20	Dr. L. Eger, Vienna	Various	39·45
„	„	Mr. A. Kreidl, Prague	Various	59·50
„	„	Prof. G. Macloskie, Princeton	Various	23·40
„	„	Prof. Kupffer, Munich	Ascidiæ	15·35
„	„	Prof. W. Krause, Göttingen	Amphioxus	5·85
„	23	Prof. Béraneck, Acad. Neuchâtel	Collection	192·15
„	26	Prof. Moseley, Oxford	Various	88·20
„	„	Mr. A. de Baranowski, Moscow	Various	62·50
May	11	Rev. Dr. A. M. Norman, Burnmoor Rectory	Various	557·
„	„	Mr. Perepelkin, Moscow	Various	50·
„	„	Prof. A. Goette, Strassburg	Various	34·80
„	„	Dr. Doederlein, Strassburg	Various	15·
„	12	Prof. Salensky, Odessa	Distaplia	34·80
„	„	Dr. C. F. Jickeli, Hermannstadt	Amphiura	8·85
„	16	Mr J. Tempère, Paris	Various	35·25
„	18	Prof. Mitsukuri, Tokio	Collection	574·90
„	„	Prof. M. Braun, Rostock	Helix	6·75
„	24	Prof. Matarazzi, S. Maria, Capua Vetere	Collection	208·
„	„	Dr. Rückert, Munich	Embryos of Dogfish	40·50
„	25	Mr. E. Marie, Paris	Collection	169·10
„	26	Prof. C. Rabl, Prague	Embryos of Dogfish	36·80
„	„	Prof. Kupffer, Munich	Petromyzon	39·75
„	28	Prof. C. Vogt, Geneva	Cerianthus	8·75
„	„	Mr. R. O. Cunningham, Belfast	Amphioxus, Torpedo	12·
„	„	Mr. A. Amrhein, Vienna	Diatomeæ	5·45
„	„	Conte Abbate Castracane, Rome	Diatomeæ	1·65
June	2	Prof. Giglioli, Florence	Fish	9·05
„	3	Prof. Hertwig, Munich	Actiniæ	22·90
„	„	Mr. E. Marie, Paris	Eggs of Octopus, &c.	18·35
„	5	Sottoprefetto Martelli, Asti	Amphioxus	
„	12	Mr. J. Chalon, Namur	Elaphis	12·50
„	„	Dr. C. Hartlaub, Nizza	Cladonema	9·60
„	17	Mr. A. Wenke, Jaromer	Mollusca	60·
„	„	Prof. Koehler, Nancy	Collection	161·15
„	25	Mr. Ch. Jefferys, Tenby	Mollusca	50·95
„	„	Mr. J. Chalon, Namur	Elaphis	13·
„	30	Dr. Irao Ijima, Science Coll., Tokio	Collection	870·
				20,572·05

Report of the Committee, consisting of Professor McKendrick, Professor Struthers, Professor Young, Professor McIntosh, Professor A. Nicholson, Professor Cossar Ewart, *and* Mr. John Murray *(Secretary), appointed for the purpose of aiding in the maintenance of the establishment of a Marine Biological Station at Granton, Scotland.*

The Committee have received the following reports from Mr. Cunningham, the superintendent, on the zoological work carried on at the Granton Laboratory and at Millport, and from Dr. Mill, the Physicist of the station, regarding work done on the Clyde sea area.

Report on the Scottish Marine Station for the year 1886–87.

Since the last meeting of the British Association the principal work carried on at Granton has been the systematic study of the Polychæta of the Firth of Forth. Mr. G. A. Ramage, Vans Dunlop Scholar of Edinburgh University, was associated with myself in this undertaking. We collected all the species we could find, more especially those living near the Laboratory in the littoral zone, and we found that the Polychæta, more particularly the sedentary forms, were abundant in the neighbourhood both in individuals and in species. We carefully determined the systematic position of each form, and investigated, as far as opportunities allowed, its life-history, anatomy, and histology. One of the most interesting results of our work was the elucidation of the peculiar structure and relations of the nephridial system in *Lanice conchilega* (Malmgren), an account of which was communicated by myself to the Royal Society of Edinburgh, and afterwards published in 'Nature' (June 16, 1887). A more complete paper, illustrated with several plates, on various points in the anatomy of the Polychæta was prepared by me for publication in the 'Quarterly Journal of Microscopical Science,' and will appear shortly in that periodical: it is now in the press. A memoir, in which the results of our investigations are fully described and illustrated, was presented in July to the Royal Society of Edinburgh, and will be published in the coming autumn in the Transactions of that Society.

In the course of the spring Mr. Rupert Vallentin, at Mr. Murray's suggestion, undertook to make an investigation of the phosphorescent organs of *Nyctophanes norvegica* (G. O. Sars) (a species of the Euphausiidæ), which occurs abundantly in certain deep areas in the Forth of Clyde. Mr. Vallentin paid several visits to Millport, and made excursions on the steam yacht 'Medusa' in order to obtain specimens of the animal. He afterwards made experiments on the phosphorescence in the living animal in the small laboratory at Millport, and brought preserved material to Granton, where he investigated the histology of the luminous organs. I afterwards joined him in preparing the results of this work for publication, and we communicated a short account of the subject to the Royal Society of Edinburgh. A more complete and illustrated paper on the subject will be published shortly in the 'Quarterly Journal of Microscopical Science.'

My own inquiries into the reproduction of *Myxine glytinosa* were continued from time to time during the winter and spring, but I was not successful in obtaining fertilised ova or embryos. I was able, however, to obtain evidence which increased the period during which I was certain that oviposition took place: the additional evidence is recorded in the 'Zoologischer Anzeiger.'

During June and July observations on the reproduction of oysters in the Firth of Forth were resumed. Steps were being taken to plant oysters and collect spat off the shore at Preston Pans, and the resources and experience available at the Granton laboratory were placed at the disposal of those engaged in this enterprise. Oysters were imported from Holland, as well as collected in the Firth, healthy spat was obtained, and arrangements were made in the aquarium at Granton for keeping this spat alive in captivity, and, if possible, securing its fixation on collectors.

The above is a sketch of the work carried on. I have now to report on the extent to which the organisation has been made use of by zoologists

not attached to it.' Mr. Ramage was working at Granton for a little more than a year, from June 1886 to July 1887. During the latter month he left in order to proceed to the island of Fernando Norotiba, as arrangements had been made through me that he should join a scientific expedition to that place, organised by Mr. Ridley, of the botanical staff of the British Museum.

Mr. R. Vallentin came to Granton on January 1, 1887, and worked there, with occasional visits to Millport, until July.

Two students of Edinburgh University, Messrs. McBryde and Kerr, spent some time in March and April in studying at the Granton laboratory.

Mr. J. Arthur Thomson, lecturer on zoology in the Extra-Mural Medical School of Edinburgh, with Mr. Murray's permission, arranged to give a vacation course in zoology at the Granton laboratory to school teachers and others in August and September. The class met on August 1. It had been arranged that I should assist in conducting this course, but I was unable to be present after the first two days, having accepted the post of naturalist at the Plymouth laboratory. The class consisted of eleven persons, and is still meeting daily at Granton.

Mr. Bury, an undergraduate at Cambridge, began to carry on zoological studies at Millport in the middle of July, and is still working there.

My own connection with the Scottish marine station is now terminated, but I still take a strong interest in its prosperity, and may state here my conviction that the existence of the Granton laboratory is of the greatest importance in exciting a healthy interest and activity in zoological science in Edinburgh. J. T. CUNNINGHAM.

Report on the Physical Work of the Station.

In connection with the physical work of the Scottish Marine Station I have, since last meeting of the Association, carried on regular temperature cruises on the Clyde sea area at intervals of about one month. On two occasions Mr. John Murray extended these excursions to the deep lochs of the west of Scotland. In many of the observations the fauna was studied in relation to the physical conditions of the water, and much information of a new and interesting nature has been collected.

Observations on the fresh-water lakes in Scotland have been continued. I have acted with Mr. Cunningham in his operations regarding the oyster culture experiment at Preston Pans, and inaugurated observations on the temperature of the sea margin there.

All the physical observations made in connection with the station are being prepared for publication. The whole of the temperature work up to July 9, 1887, is passed for press, and will appear in the forthcoming 'Journal of the Scottish Meteorological Society.' The observations of density will be given in a later number.

The improved thermometers and water-bottles were exhibited at the Exhibition of Marine Meteorological Instruments held by the Royal Meteorological Society in March last, and several have subsequently been supplied to zoologists in various parts of the country for use on dredging excursions.

My principal papers since last year have been—(1) 'On the Physical Conditions of Water in the Clyde Sea Area,' read to the Philosophical

Society of Glasgow in February, and published in abstract with additions in 'Nature,' vol. xxxvi. pp. 37–39, 56–58. (2) 'Marine Temperature Observations,' read to the Royal Meteorological Society in March, and about to be published in their 'Quarterly Journal.' (3) 'On the Salinity and Temperature of the Moray Firth,' read to the Royal Society of Edinburgh in July last, and to appear in the next part of the 'Proceedings.' (4) 'Recent Physical Research in the North Sea,' a criticism of the work of the German gunboat 'Drache,' in the 'Scottish Geographical Magazine' for August; and (5) 'Contributions to Marine Meteorology resulting from the three years' work of the Scottish Marine Station,' read to the Scottish Meteorological Society in July and to Section A of the present meeting.

HUGH ROBERT MILL, *D.Sc.*

The Committee beg to recommend that a further grant of 100*l.* be made by the Association to aid in the maintenance of the Scottish Marine Station during the ensuing year; and that Mr. John Murray, Dr. Alex. Buchan, Professor McKendrick, and Professor Chrystal be the Committee. Mr. John Murray to be Secretary.

JOHN MURRAY, *Secretary.*

Report of the Committee, consisting of Mr. THISELTON DYER (*Secretary*), Mr. CARRUTHERS, Mr. BALL, Professor OLIVER, *and* Mr. FORBES, *appointed for the purpose of continuing the preparation of a report on our present knowledge of the Flora of China.*

THE grant made by the Association has enabled the Committee to proceed with this important work, the third part of which, carrying the enumeration down to the end of the Rosaceæ, is now in the hands of the printer, and the fourth part has been commenced. Since the work was begun, about two years ago, several collections of dried plants have been received at Kew from China; notably, a very extensive one from Dr. A. Henry, made in the little known district of Ichang, in the province of Hupeh, in the very centre of China. And the trustees of the British Museum have acquired the herbarium of the late Dr. Hance, containing the types of the large number of species published by him from time to time during a long residence in the country. Dr. Henry's collection includes a large number of novelties, besides the addition of many Himalayan and Japanese forms not previously known, from China; and Dr. Hance's herbarium greatly facilitates the limitation of the species where comparisons with his types are necessary. The published parts of the report have been freely distributed among English residents in China, and have no doubt been the means of stimulating some of them to greater activity now that they perceive that there is a probability of the results of their exertions being promptly published. Dr. Henry is specially interested in the origin of the numerous drugs used in Chinese medicine, and, aided by our determinations of the plants, we may assume that he will be able to make a substantial addition to our knowledge of the Chinese pharmacopœia. Mr. Ford, too, the Superintendent of the Hong Kong Botanic Garden, takes a lively interest in the work, and has rendered valuable assistance, doubtless with advantage to the establishment under his charge.

Several eminent foreign botanists have alluded to the work as of great

interest and importance, and the Committee have much satisfaction in reporting that circumstances are now favourable to more rapid progress in the future than hitherto. Simultaneously with the appearance of our Index Floræ Sinensis, a French botanist, M. Franchet, is publishing a very extensive collection of plants made by French missionaries in Yunnan, a province from which there is almost nothing in the London herbaria; hence his labours supplement ours and cover a distinct floral region.

The Committee recommend their reappointment, and that a further grant of £100 be placed at their disposal.

Report of the Committee consisting of Canon A. M. NORMAN, Mr. H. B. BRADY, Mr. W. CARRUTHERS, Professor HERDMAN, Professor W. C. M'INTOSH, Mr. J. MURRAY, Professor A. NEWTON, Mr. P. L. SCLATER, *and* Professor A. C. HADDON (*Secretary*), *appointed for the purpose of considering the question of accurately defining the term 'British' as applied to the Marine Fauna and Flora of our Islands.*

A CIRCULAR giving in detail alternative boundaries for a British marine area, and maps and sections illustrating the same, was distributed to the members of the 'British Marine Area Committee,' as well as to a large and representative number of naturalists interested in marine zoology. As was to be expected, the replies showed that great diversity of opinion exists not only as to the desirability of limiting a British marine area, but also as to how far such an area should extend.

A tabulation of the replies was subsequently forwarded to the members of the Committee, and the following statements appear to express the views of the majority.

It may be desirable, for the convenience of curators of museums and the compilers of faunistic works, to limit a marine area which may be more particularly described as 'British.'

The British Marine Area may be conveniently subdivided into a shallow-water and into a deep-water district.

The 100-fathom contour is a natural boundary line for the former off the north and west coasts of the British Islands for the following reasons: 1. It is defined on all charts; 2. The Admiralty soundings are very complete down to that depth; 3. The 100-fathom line roughly corresponds with the beginning of the declivity of the continental plateau; 4. There is a marked change in the fauna about that limit; 5. Most of the dredgings of British naturalists have been taken within that contour.

The only boundary on the south and east is the half-way line between Great Britain and the Continent: this should include the Dogger Bank.

The above district may be termed 'The British Marine Shallow-water District.'

The deep-water district of the British Marine Area may be regarded as extending from 100 to, say, 1,000 fathoms—that is, to the commencement of the abysmal floor of the ocean. As these depths occur only off the north and west coasts, this region may be termed 'The British Atlantic Slope District.'

The Channel Islands lie outside the British Marine Area proper.

Report of the Committee consisting of Professor M. FOSTER, Professor BAYLEY BALFOUR, Mr. THISELTON-DYER, Dr. TRIMEN, Professor BOWER (*Secretary*), Professor MARSHALL WARD, Mr. CARRUTHERS, *and* Professor HARTOG, *appointed for the purpose of taking steps for the establishment of a Botanical Station at Peradeniya, Ceylon.*

THE Committee for the purpose of taking steps for the establishment of a botanical station at Peradeniya, Ceylon, report that they have communicated with Dr. Trimen since his return to his duties at Peradeniya, and that he has provided them with the following memorandum on Peradeniya as a site for a botanical station :—

'Ceylon is the only British colony in the tropics which possesses a botanic garden of importance, provided also with a good library and herbarium, arranged, and available for reference and study.

'Though the immediate neighbourhood of Peradeniya gardens is mostly land which has been or is now under cultivation, and thus does not exhibit the natural wild vegetation of the Eastern tropics in a very characteristic manner, yet there are within easy reach by railway and road all descriptions of country, including high mountains, and the south and west coasts ; and on the whole Peradeniya is favourably placed for the study and collection of tropical plants of all types (the contents of the gardens themselves being also taken into consideration).

'There is no special laboratory for microscopic and other work here, but a large room in the museum building is well suited for the purpose. There is at present no apparatus there. In the gardens themselves there is no suitable accommodation for students, but in the close neighbourhood are several bungalows, some of which are generally unoccupied. That in which Professor Bower lived in 1886 is quite close to the gardens and could easily accommodate two men. It is possible that if there were any prospect of a succession of students this little house might be acquired by the Government, and furnished with the few requisites for tropical life.

'The climate is very healthy; elevation 1,540 feet above the sea; mean annual temperature about 77° F. ; rainfall about 90 inches, pretty evenly distributed throughout the year, December to April being the driest months.

'(Signed) HENRY TRIMEN, Director.'

In addition to the advantages, thus noted by Dr. Trimen, which Peradeniya possesses over alternative sites, it may be mentioned that it is the residence of the permanent director of the gardens in Ceylon ; also that the extensive garden would supply large quantities of material suitable for research ; further, that a large number of the plants in the garden are labelled, while attempts are being made to arrange the plants as far as possible according to their natural affinities. Again, there is attached to the gardens a body of experienced native collectors, whose duty it is to bring in plants from remote districts, and thus access is gained to plants which would not otherwise be readily obtained. These are facts of importance which contribute to make Peradeniya a most fitting place for the visits of students who have not had any previous experience of a tropical flora; and this, it must be remembered, will be the position of most of those who will wish to study there. On these grounds your Committee

are of opinion that Peradeniya is a most suitable place for the establishment of a botanical station in the Eastern tropics. From the memorandum of Dr. Trimen it would appear that laboratory accommodation is already supplied, and a comparatively small outlay would be required to provide apparatus. The Committee therefore request that they be reappointed, and that a grant of 50*l.* be placed at their disposal to provide this apparatus.

Report of the Committee, consisting of Professor VALENTINE BALL, Mr. H. G. FORDHAM, Professor HADDON, Professor HILLHOUSE, Mr. JOHN HOPKINSON, Dr. MACFARLANE, Professor MILNES MARSHALL, Mr. F. T. MOTT (*Secretary*), Dr. TRAQUAIR, *and* Dr. H. WOODWARD, *appointed for the purpose of preparing a Report upon the Provincial Museums of the United Kingdom.*

WE propose to treat the subject entrusted to us under the following sectional headings, viz.:—

1. Preliminary Sources of Information.
2. Methods adopted for obtaining correct Statistics.
3. Tables of General Statistics.
4. Discussion of Details.
5. The Ideal Museum.
6. Practical Suggestions for approaching the Ideal.

We include in our inquiry all Museums out of London to which the public can obtain access.

1. PRELIMINARY SOURCES OF INFORMATION.

(*a*) A 'List of Museums in the United Kingdom,' prepared in 1876 by the Science and Art Department, a copy of which was supplied to us on application to the Department. This was stated to be 'incomplete,' but it contained the names of 158 museums, exclusive of those in London.

(*b*) A return to an Order of the House of Commons in 1884, giving a list of 41 museums established under the Public Libraries Act.

(*c*) A list of local scientific societies contained in the Report of the Local Scientific Societies Committee, presented to the Association at Southport in 1883, and published in the annual volume for that year.

This list indicates those societies which were known to possess museums.

(*d*) A circular posted to the town clerks of all the municipal boroughs in the United Kingdom (240), asking for the names of all museums in their respective towns and districts. To nearly the whole of these circulars we received very courteous replies, with the names of many museums previously unknown to us.

(*e*) Information from the members of the Committee and friends.

2. METHODS ADOPTED FOR OBTAINING CORRECT STATISTICS.

From the various sources of information enumerated above a preliminary list of museums was drawn up and printed, containing, in—

England	190	Total, 240.
Wales	8	
Scotland	27	
Ireland	15	

Some of these were afterwards found to have been sold or otherwise dispersed. Some had never been actually established. Some were erroneously named; others were art galleries only; and in a few cases two museums in the same town had been united into one. As a final result we have found 211 museums which seem properly to come within the scope of our inquiry.

In addition to this preliminary list we drew up a series of questions arranged in two schedules, A and B. Schedule A contained seven questions relating to primary statistics, intended to be incorporated in a published list. Schedule B contained thirty-six questions on matters of detail. These schedules were printed with space for replies, and posted, with copies of the preliminary list of museums and a printed circular explaining the object in view, to 'The Curator' of nearly every museum on the list.

Schedule A.

1. Name of town and county. **2.** Name of museum and street or building in which it is situated. **3.** Date of foundation or opening. **4.** Name and address of curator or other principal officer. **5.** List of collections and of subjects illustrated, viz.:—

General collections, including local specimens, unless these are kept separately, or distinguished by special labels		Local and special collections. If kept separately, or distinguished by special labels, not otherwise		Loan collections	
Subjects	Approximate number of specimens	Particulars	Approximate number of specimens	From whom	Approximate number of specimens
Geology . . . Zoology . . . Botany . . . Archæology . Anthropology.					

6. On what terms and at what hours is the museum open to the public? **7.** Remarks.

Date, Signature of Curator,

Schedule B.

1. By whom was the museum founded? **2.** To whom does it now belong? **3.** How is it supported? **4.** How is it governed? **5.** State in round numbers the annual cost of maintenance, viz.:—Rent and taxes; salaries and wages; cases; purchase of specimens; mounting of specimens; other expenditure. **6.** What is the staff employed? and during what hours? **7.** Under what tenure and from what owner are the buildings or rooms held? **8.** State the number of rooms or galleries, their length, breadth, and height, and how lighted and warmed. **9.** State the general arrangement of the cases in the principal rooms, either in words or by a rough sketch. **10.** How are the cases made dust-proof? **11.** State any special details of fittings. **12.** State any special methods adopted for preserving or exhibiting the specimens. **13.** Are the natural history specimens set up pictorially with rock, grass, water, &c., showing their mode of life, or merely on separate pegs or stands? **14.** Is any attempt made to exhibit the *family life* of birds and animals, showing male, female, young, eggs, nest, &c., grouped together? **15.** Are the natural history specimens generally in good condition, or dirty and grub-eaten and requiring re-

newal? **16.** Are all the specimens illustrating each group—whether skeletons, stuffed, or bottled—arranged together, or are the skeletons and the bottles kept apart from the stuffed specimens? **17.** Are the fossils arranged zoologically with the recent specimens, or stratigraphically? **18.** If there are any purely local collections, give some further account of these than in the answer to Question 5, Schedule A, and say whether they are kept apart from the other specimens, or only distinguished by special labels. **19.** State the principal specialities in your district which ought to be represented by special collections but are not so at present. **20.** Are there any collections especially arranged for *educational* purposes? If so, state method of arrangement or classification. **21.** Have you any technical or industrial department in the museum? **22.** Are there any classes or any arrangements for systematic teaching at the museum? **23.** Is the museum much used for *study* by local naturalists, or archæologists, or medical students? **24.** Are any facilities offered to students, such as private rooms, tables, or microscopes; and are they allowed, under any conditions, to handle the museum specimens? **25.** Are the rooms used for any other purposes when the museum is not open? **26.** Are there any aquaria or vivaria in the museum? **27.** What catalogues or handbooks of the museum have been published? (Please inclose copies.) **28.** How are the duplicates and surplus stores kept and arranged? Have you any large stock of duplicates? **29.** If the museum belongs to the public, and any local society is in any way connected with it, say what benefit the museum receives from such connection. **30.** Are there many donations of specimens to the museum annually, and from what class of persons chiefly? **31.** What style of labelling is adopted? (If you have a special form of label, please attach a specimen.) **32.** If the museum has a library of scientific or archæological works for the use of the curator or students, state about the number of volumes and the average annual increase. **33.** Can you give any estimate of the average *weekly* number of visitors? How is the estimate arrived at? **34.** Is the museum centrally situated, or otherwise, in reference to the population? **35.** At what time of the day is the museum most visited, and how is it affected by public holidays? **36.** Make here any remarks upon matters not included in the foregoing inquiries, or any suggestions of your own as to improvements in the general management of provincial museums.

Name of Museum. Signature of Curator,

Date.

The returns came in slowly. Some of them were very full and satisfactory; others were extremely meagre. A large book was prepared in which to enter up in tabular form the replies to the various questions as they arrived.

Two months after the schedules had been distributed a printed post-card was sent to each curator who had made no return, and a month later another card, marked 'Urgent,' was posted to those still in arrear. Many had to be specially written to for important details omitted in their replies, and there are still eight museums from which we have been unable to get any information.

Some asked for duplicate schedules in order to keep copies of their replies. In many cases the schedules had miscarried, owing probably to there being no recognised 'curator' to a number of the smaller museums. On information of this fact being received, fresh copies were forwarded to the secretary or other officer.

The statistics finally obtained afford sufficient data for comparing the size and special characteristics of the various museums, and have enabled us to arrange them into four classes, taking into consideration the superficial area of the rooms, the size and character of the collections, the annual cost, the staff, and the number of visitors.

A few of the museums have been personally visited by members of the Committee, but it has not been found practicable at present to carry out this method on any extensive or systematic plan.

3. TABLES O

TABLE I.—*List o*

NOTE.—*The collections are named in the order of their numerical importance in eac*
M. stand

No.	Town and County	Name and Locality of Museum	Date of Foundation	Name and Address of Curator, Principal Officer, or Owner	Class
	ENGLAND—				
1	Aldborough, Yorks	'M. Isurianum,' Aldborough Manor, near Boroughbridge	—	A. S. Lawson, Esq., Owner, Aldborough Manor	4
2	Alnwick, Northumberland	The Castle M., Alnwick Castle .	—	Duke of Northumberland, Owner	2
3	Alton, Hants . .	The 'Curtis' M., Mechanics' Institute	1855, 1880	William Curtis, Cur., Alton . .	2
4	Andover, Hants .	The Institute M., Bridge Street .	1854	Ernest Collier, Cur., The Vicarage	4
5	Aylesbury, Bucks .	Bucks Architectural and Archæological M., Church Street	1854	Robert Gibbs, Cur., Aylesbury .	4
6	Bakewell, Derbyshire	Bingham's M., Bath Street . .	1873, 1885	L. F. Bingham, Owner, Bakewell	4
7	Barnard Castle, Durham	The Bowes M.	1869	Owen S. Scott, Cur., Bowes M., Barnard Castle	2
8	Bath, Somerset .	M. of the Royal Literary and Scientific Institution, Terrace Walks	1825	T. F. Plowman, Gen. Secretary .	2
9	Berwick-on-Tweed, Durham	Berwick M., High Street . .	1869	John Scott, Cur., 103 High Street	3
10	Birmingham, Warwickshire	M. and Art Gallery	1885	Whitworth Wallis, F.R.G.S., Director	1
11	,, ,,	Aston Hall M., Aston Park . .	1864	Alfred J. Rodway, Cur., Aston Hall	2
12	,, ,,	M. of the Natural History and Microscopical Society, Mason College	1864	W. N. Wilkinson and W. P. Marshall, Hon. Secs.	4
13	Blackburn, Lancashire	Public Library and M., Library Street	1862	David Geddes, Cur. . . .	2
14	Bolton, Lancashire	The Chadwick M., Park Road .	1884	W. W. Midgley, Cur., Museum .	1
15	Bootle, Lancashire	Free Public Library and M., Oriel Road	1885	—	[illegible]
16	Bradford, Yorks .	Free Library and Art M., Darley Street	1879	Butler Wood, Cur., 1 Scott Street	[illegible]
17	Brighton, Sussex .	Free Library and M.	1883	Benjamin Lomax, F.L.S., Cur.	[illegible]
18	,, ,, .	M. of British Birds, Dyke Road .	—	E. T. Booth, Owner . . .	[illegible]
19	Bristol, Gloucestershire	M. and Library, Queen's Road .	1867	Edward Wilson, F.G.S., Cur., Museum	[illegible]

NERAL STATISTICS.

ovincial Museums.

seum. When two dates are given, the second refers to removal to present premises.

Museum.

Collections		Supported by	No. of Visitors weekly	Duplicates for Exchange	Terms of Admission	Remarks
General	Local					
—	Arch. (Roman remains, &c.)	Owner . .	—	—	Free on application	Private
ch. (Egyptian, &c.), Geo., Zoo., Anth.	Arch.	"	—	—	Free on order	"
o., Zoo., Arch., Anth., Bot.	Geo., Zoo., Arch., Bot.	The Institute and Fees	Few	—	2*d.* daily .	Good for small town
o. Arch., Geo., Submarine cables, &c.	Arch., Geo., Anth.	The Institute	2	—	Free daily	
ch.	—	Local Society	—	—	Free on application	Small and neglected
o. (White Watson's coll.), Zoo., Shells, Models, Autographs, &c.	—	Owner . .	100	. .	Free	
t, Italian and Spanish paintings, pottery and porcelain	—	Endowment	—	—	Free on application	Grand design, but incomplete at death of founder, and not yet formally opened
o., Bot., Anth., Arch.	Geo. (coll. of C. Moore, F.G.S. & W. Lonsdale, F.G.S.), Zoo. (Duncan and Lockey colls.), Bot. (Rev. L. Blomefield's coll.)	The Institution and Fees	140	Geo. and Zoo.	Free, 4 days; 6*d.* 2 days	
o. (few), Zoo. (few), Arch. (few)	Bot., Zoo., Geo., Arch.	Town Subscription and Fees	30	—	1*d.* daily .	Intended to be purely local
t (industrial and decorative)	—	Rate . .	22,000	—	Free daily, and Sundays 2 to 5	Open on Sunday; loan from S.K.
o., Geo., Art (industrial and fine), Anth., Bot., Arch.	Anth.	"	2,000	Geo. and Zoo.	Free daily	An old mansion
o., Zoo., Bot., Microscopy	—	Local Society	—	—	Members only	Very small
o., Zoo., Arch., Art (industrial and fine), Bot., Anth.	—	Rate . .	1,200	Geo., Bird skins and eggs, &c.	Free daily	
o., Geo., Arch., Bot., Tech. Art (industrial and fine)	—	"	3,500	—	"	Legacy of 5,000*l.* towards building
o., Geo. (purchased from Royal Institution, Liverpool)	—	"	—	—	"	Not yet opened
t (industrial and fine), Geo., Anth.	—		6,000	—	"	Loan from S.K.
o., Zoo., Bot., Arch., Anth., Porcelain	Geo.	"	1,500	Given away .	Free daily	
o. (British birds only)	—	Owner and Fees	—	—	1*s.* daily .	Good of its kind
o., Zoo., Anth., Arch., Bot., Egyptian Ant., Materia Medica	Geo., Zoo. . .	Subscription, Endowment and Fees	240	Geo. .	2*d.* 3 days; 6*d.* 3 days	

TABLE I.—LIST OF PROVIN

No.	Town and County	Name and Locality of Museum	Date of Foundation	Name and Address of Curator, Principal Officer, or Owner	Class
	ENGLAND—*cont.*				
20	Burslem, Staffordshire	Wedgwood Institute, Queen Street	—	Thomas Hulme, Hon. Cur., Woodleigh, Longport	3
21	Burton-on-Trent, Staffordshire	M. of the Nat. History and Archæological Society, The Institute, Union Street	1882	Frank E. Lott, Hon. Cur., Bridge Chambers	4
22	Bury-St.-Edmunds, Suffolk	Bury-St.-Edmunds M., The Athenæum, Angel Hill	1840	Henry Rigg, Hon. Cur., Babwell Priory	3
23	Caerleon, Monmouth	Caerleon M.	—	F. J. Mitchell, Esq., J.P., Hon. Sec., The Grange, Llanfechfa, Caerleon	3
24	Cambridge, Cambridgeshire	M. of General and Local Archæology, Little St. Mary's Lane	1884	Baron Anatole Von Hügel, 53 Chesterton Road	1
25	" "	The Woodwardian M. Trin. Coll. .	1728	Prof. T. McKenny Hughes, M.A., F.G.S., Cur.	1
26	" "	The FitzWilliam M., Trumpington Street	—	C. Waldstein, M.A., Ph.D., Director, King's College	1
27	" "	Mineralogical M., New Museums .	1822	Prof. W. J. Lewis, Cur. . .	1
28	" "	Botanical M. and Herbarium .	—	Prof. C. C. Babington, M.A., F.R.S., Cur., 5 Brookside	1
29	Canterbury, Kent .	Canterbury M.	1825, 1847	A. D. Blaxland, Cur. . . .	3
30	Carlisle, Cumberland	Carlisle M., Finkle Street . .	1835, 1877	R. S. Ferguson, M.A., Hon. Cur., Sowther Street	2
31	Chard, Somerset .	Chard M.	1882	—	4
32	Chatham, Kent .	M. of School of Military Engineering	—	—	1
33	Chelmsford, Essex	Essex and Chelmsford M. . .	1828	Rev. R. E. Bartlett, Hon. Cur. .	3
34	Cheltenham, Gloucestershire	The Pierson M., Cheltenham College	1870	Charles Pierson, Hon. Cur., 3 Blenheim Parade	2
35	Chester, Cheshire .	The Grosvenor M., Grosvenor Road	1886	Robert Newstead, Cur. . . .	2
36	Chesterfield, Derbyshire	M. of Chesterfield and Mid-Counties Institution of Engineers	—	Rev. J. M. Mello, M.A., F.G.S., Hon. Cur.	3
37	Chichester, Sussex	M. of the Literary Society and Mechanics' Institute, South Street	1831	Joseph Anderson, Jun., Hon. Cur., Aere Villa	2
38	Cirencester, Gloucestershire	The Corinium M., Tetbury Road .	1856	Christopher Bowley, Hon. Cur., Siddington House	3
39	" "	M. of Royal Agricultural College .	1845	Rev. J. B. McClellan, M.A., Principal of the College	2
40	Coalbrookdale, Shropshire	M. of the Literary and Scientific Institution	1858	Isaac Dunbar, Cur. . . .	3
41	Colchester, Essex .	Colchester Free M., The Castle .	1846	Frederick Spalding, Cur. . .	3
42	Croydon, Surrey .	M. of Surrey Arch. Society, Public Hall	1856	Thomas Milbourn, Hon. Sec., 12 Beaulieu Villas, Finsbury Park	4
43	Darwen, Lancashire	Public Library and M., Church Street	1839, 1871	E. Neville, Cur.	4
44	Derby, Derbyshire .	Derby Free M., Wardwick . .	1879	W. Crowther, Cur., Wardwick .	2
45	Devizes, Wiltshire .	Wilts Arch. and Nat. Hist. M., Long Street	1853	Henry Cunningham, Hon. Cur., Devizes	2
46	Devonport, Devon .	Free Public Library and M., Duke Street	1882	Charles R. Rome, Librarian . .	3
47	Dorchester, Dorset	Dorset County M., High West Street	1846, 1883	H. J. Moule, Cur., Dorchester .	2
48	Dover, Kent . .	Dover M., Market Square . .	1836	E. F. Astley, M.D., Hon. Cur., 29 Parade	2
49	Dudley . . .	M. of Geol. Soc. and Field Club .	—	W. Madeley, Sec.	3
50	Dulwich, Surrey	Dulwich College M., College . .	—	H. M. Stewart, Hon. Cur., Dulwich College	3
51	Durham, Durham .	University M.	1833	J. Cullingford, Cur., Palace Green	3
52	Eastbourne, Sussex	The Caldecott M. . . .	1870	C. J. Muller, Trustee, 4 Bolton Road	3
53	Eton, Bucks . .	Eton College M. .	1879	F. Drew, F.G.S., Hon. Cur., Eton College	3

L MUSEUMS—*continued.*

Collections		Supported by	No. of Visitors weekly	Duplicates for Exchange	Terms of Admission	Remarks
General	Local					
..tery only	—	Rate	—	—	Free daily	Loan from S.K.
). (few), Zoo. (few)	Bot., Arch., Anth.	Local Society	—	Geo., Zoo., Bot.	Free by order	
)., Bot., Arch., Zoo., .nth.	—	Borough Funds	50	Geo., Zoo.	Free daily	
—	Arch. (Roman)	Local Society	—	—	—	
:h., Anth.	Arch.	The University	50	Anth.	Free daily	
)., Zoo.	Geo.	" "	No account kept	Geo.	"	
.h., Anth.	—	" "	—	—	"	
ieralogy	—	" "	Few	Minerals	"	
.	—	" "	—	—	"	
)., Anth., Arch., oo., Bot.	—	Rate	500	—	"	
., Geo., Arch., .nth.	Geo., Zoo., Bot., Arch., Anth.	Boro' Fund and Fees	100	—	2*d.* daily	
)., Arch., Anth.	—	Boro' Fund	Few	—	Free daily	
lels of Forts, :ridges, &c.	—	The Crown	—	—	Free on application	—
—	—	Local Society and Fees	—	—	1*s.* daily	
)., Zoo., Bot., Arch., nd. Art	—	The College	6	Geo.	Free one day	
)., Zoo.	Zoo., Arch.	Subscriptions and Fees	—	—	Free one day; 6*d.* five days	Loan from S. K.
)., Arch.	Geo.	The Institution	—	Few	Free daily	
)., Zoo., Bot., Arch., .nth.	Geo.	The Institution	17	Birds	3*d.* daily	
—	Arch. (Roman)	Earl Bathurst	—	—	Free daily	
)., Bot., Chem., Agri., Surg., Zoo.	Geo.	The College	—	Geo.	Free to visitors	
.	Geo.	The Institution and Fees	Few	—	Small charge	
:h.	Arch.	Boro' Fund	250	Arch.	Free daily	
:h., Anth.	—	Local Society	—	—	Free on order	Very small
—	Geo., Zoo., Bot., Arch.	Rate	Few	—	Free daily	
)., Zoo., Arch., .nth.	Geo., Zoo., Bot., Arch.	"	—	Few	" "	
)., Zoo., Bot., Arch., .nth.	Arch.	Local Society and Fees	30	—	Free one day; 6*d.* five days	
).	—	Rate	Few	—	Free daily	
)., Zoo., Arch., .nth.	Geo., Arch., Zoo.	Subscriptions and Fees	60	Geo.	2*d.* daily	
)., Zoo., Bot., Arch.	Zoo.	Rate	50	Geo.	Free five days	
).	Geo.	Local Society	Few	—	Free on application	
)., Zoo., Bot.	—	Subscriptions	—	—	Free to visitors	Private
., Geo., Arch.	Bot., Arch.	The University	—	—	2*d.* daily	
).	Zoo., Bot., Arch.	Subscriptions and Fees	15	—	3*d.* 3 days	
)., Zoo.	Zoo., Anth.	The College	—	—	Free on application	

TABLE I.—LIST OF PROVI

No.	Town and County	Name and Locality of Museum	Date of Foundation	Name and Address of Curator, Principal Officer, or Owner	Class
	ENGLAND—*cont.*				
54	Exeter, Devon	Albert Memorial M., Free Library	1868, 1870	James Dallas, F.L.S., Cur., 21 Wonford Road	1
55	Folkestone, Kent	Public Library and M.	1870	Henry Ullyett, B.Sc., Hon. Cur., Lyell House	3
56	Frome, Somerset	M. of the Literary and Scientific Institution	1845	G. A. Daniel, Hon. Sec.	3
57	Giggleswick, Yorks.	Giggleswick School M.	1887	Rev. G. Style, M.A., Head Master	3
58	Glastonbury, Somerset	Glastonbury M., Town Hall	1886	G. L. Bulleid, Hon. Sec.	3
59	Gloucester, Gloucestershire	County M., Brunswick Road	1870	W. G. Lucy, F.G.S., Hon. Cur., Brookthorpe	3
60	Gosport, Hants.	Haslar Hospital M.	1827	Dr. Walter Reid, Fleet Surgeon, Director	1
61	Greenwich, Kent	Naval M., Royal Naval College	1874	Wm. Rees, R.N., Hon. Cur., 23 Park Place	1
62	Haileybury, Herts.	Haileybury College M.	—	A. de. M. Hemsley, College	4
63	Halifax, Yorks.	M. of Literary and Phil. Society	1830	J. W. Davis, F.G.S., Hon. Cur., Chevinedge	1
64	" "	Mr. J. W. Davis's M., Chevinedge	—	J. W. Davis, F.G.S., Owner	2
65	Hereford, Herefordshire	Hereford Free Library and M., Broad Street	1874	A. M. D. Gott, Cur.	2
66	Huddersfield, Yorks.	Beaumont Park M., Woodside Road	1880	S. L. Mossley, Owner, Museum	3
67	" "	M. of Technical School and Mechanics' Institute	—	Austin Keen, Secretary	4
68	Hull, Yorks.	—	—	—	—
69	Huntingdon, Hunts	M. of Literary and Scientific Institution, Institution Hall	1840	Wm. Bryant, Hon. Cur., Huntingdon	4
70	Ipswich, Suffolk	Ipswich M.	1849	Dr. J. E. Taylor, F.L.S., Cur.	1
71	Kendal, Westmoreland	M. of the Literary and Scientific Institute, Strickland Gate	1835	Joseph Severs, Hon. Sec.	3
72	Keswick, Cumberland	M. of Local Nat. Hist., Town Hall	1877	John Birkett, Hon. Cur., Market Place	3
73	King's Lynn, Norfolk	King's Lynn M., Athenæum Buildings	1844	E. A. Atmore, Hon. Cur., High Street	2
74	Kirkleatham, Yorks.	Kirkleatham M., Turner Hospital		Trustees for the heir of the Kirkleatham Estate	4
75	Lancaster, Lancashire	Mechanics' Institute M.	—	George Kelland, Hon. Sec.	4
76	Launceston, Cornwall	M. of the Scientific and Historical Society	1879	W. Wise, Hon. Cur., Broad Street	4
77	Leeds, Yorks.	Corporation M., Municipal Buildings	1884	James Yates, Cur., Public Library	4
78	" "	M. of the Philosophical and Literary Society, Park Row	1822	Professor L. C. Miall, F.G.S., Cur., Yorkshire College	1
79	" "	M. of Yorkshire College Medical Department, Park Street	—	E. H. Jacob, M.D., Cur., Yorkshire College	3
80	" "	M. of Yorkshire College Biological Department, College Road	—	—	—
81	" "	M. of the Architectural Society, Infirmary Buildings	1882	L. F. Hicks, Cur., Infirmary Buildings	2
82	Leek, Stafford.	Nicholson Institute M., Stockwell Street	1884	William Hall, Cur., Nicholson Institute	3
83	Leicester, Leicestershire	Town M., New Walk	1836, 1849	Montagu Browne, F.Z.S., Cur., Aylestone Road	1
84	Lewes, Sussex	M. of the Sussex Arch. Society, The Castle	—	Robert Crosskey, Hon. Cur., The Castle	3
85	Lichfield, Staff.	Free Library and M., Bird Street	1859	J. P. Roberts, Cur.	3
86	Liverpool, Lancashire	Free Public M., William Brown Street	1852, 1861	T. J. Moore, Cor. Mem. L.S.L., Cur., Museum	1
87	" "	M. of the Royal Instit., Colquitt Street	1814	Edward Doling, Cur., Royal Institution	1
88	" "	Zoological M. of University College, Ashton Street	1881	Prof. W. A. Herdman, D.Sc., Cur., University College	3
89	Ludlow, Shropshire	M. of Natural History Society, Mill Street	1842	Charles Fortey, Hon. Cur., Abbey Villa	3

.L MUSEUMS—*continued.*

Collections: General	Collections: Local	Supported by	No. of Visitors weekly	Duplicates for Exchange	Terms of Admission	Remarks
o., Geo., Arch., Bot., Anth.	Geo., Zoo., Arch.	Rate	500	Geo., Zoo.	Free daily	
o., Zoo.	Geo., Zoo.	Rate	—	—	Free daily	
o., Zoo., Arch.	—	Local Society	5	—	Free on order	
o., Zoo.	—	The School	—	—	Free	
ch.	Arch.	Local Society	—	—	4*d.* 5 days, 2*d.* 1 day	
—	Geo., Zoo., Arch.	" "	—	—	Small charge	
o., Surgery, Anth.	—	The Admiralty	60	—	Free daily	
odels of Ships, Dockyards, &c.	—	The Crown	—	—	Free 5 days	
o., Zoo.	—	The College	—	—	—	For teaching only
o., Geo., Arch.	Geo., Zoo., Bot., Arch.	Local Society	400	—	1*d.* daily	
o.	Geo.	Owner	20	—	Free on application	
—	Geo., Zoo., Arch.	Rate	—	—	Free daily	
o., Geo.	—	The Owner	—	Zoo.	1*d.* daily	
dustrial Art, Zoo.	—	The Institute	—	—	—	
—	—	—	—	—	—	
ientific Apparatus, Geo.	—	Local Society	—	—	Members only	
o., Geo., Arch., Anth.	Zoo., Geo., Bot.	Rate	1,500	—	Free daily	
o., Zoo.	Bot.	Local Society	40	Geo.	Free daily	
—	Geo., Zoo., Bot., Arch.	Local Society and Fees	40	—	1*s.* daily	
o., Zoo., Bot., Arch.	Zoo., Bot.	Subscriptions	80	Few	Free daily	
ch., Anth.	—	The Owners	—	—	"	
o., Zoo.	—	The Institute	—	—	—	Small and neglected
o., Zoo., Bot., Arch.	—	Local Society	—	—	—	
dustrial and Fine Art	—	Rate	2,500	—	Free daily	Loan of 4 cases from S.K. only
o., Geo., Arch., Anth., Bot.	—	Local Society and Fees	500	Few	1*d.* daily	
thology, Anatomy	—	The College	—	—	Free to visitors	For College students
o.	—	"	—	—	"	"
ilding appliances	—	Exhibitors' Rents	—	—	Free daily	
lustrial and Fine Art	Geo., Zoo.	The Institute	200	—	1*d.* daily	Loan from S.K. chiefly
o., Geo., Arch., Bot., Anth., Ind. Art	Geo., Zoo., Bot., Arch.	Rate	2,000	Geo., Zoo.	Free daily	Loan from S.K.
ch.	Arch.	Local Society and Fees	—	—	Small charge	
o., Zoo., Bot., Arch., Anth.	—	Rate	—	—	Free daily	
o., Geo., Arch., Bot., Anth., Historic Art Treasures	Zoo., Geo.	"	7,000	Geo., Zoo., Bot.	"	
o., Anth., Fine Art	—	Local Society	—	—	Free one day	
o.	—	The College	—	—	Free on application	
o., Zoo., Arch.	—	Local Society and Fees	50	Geo.	3*d.* daily	

TABLE I.—LIST OF PROVI[NCIAL]

No.	Town and County	Name and Locality of Museum	Date of Foundation	Name and Address of Curator, Principal Officer, or Owner	Class
	ENGLAND—*cont.*				
90	Macclesfield, Cheshire	School of Art M., Park Lane	1883	—	3
91	Maidstone, Kent	M. & Public Library, Faith Street	1858	Edward Bartlett, Cur., Museum	1
92	Malton, Yorkshire	M. of Field Naturalists and Scientific Society, Yorkersgate	1880	S. Chadwick, Hon. Cur., Norton	2
93	Malvern, Worcestershire	Malvern College M.	—	George E. Mackie, Hon. Cur., 1 College Grounds	3
94	Manchester, Lancashire	Manchester M., Owens College	—	Prof. W. Boyd Dawkins, M.A., F.R.S., Owens College	1
95	" "	Art Museum, Ancoats Hall	1886	Henry Brooke, Cur., Ancoats Hall	1
96	" "	Queen's Park M. and Art Gallery, Queen's Park	1884	C. G. Virgo, Cur., 2 Green Mount, Queen's Park	1
97	Marlborough, Wilts.	Marlborough College M.	—	Rev. T. N. Hart Smith, Hon. Cur., The Green	2
98	Melton Mowbray, Leicestershire	Melton M., The Bede House	1847	—	4
99	Middlesborough, Yorks.	Middlesborough M., Zetland Road	1887	W. Y. Veitch, Hon. Cur., 37 Grange Road	3
100	Newbury, Berks.	Newbury M.	1843	M. Palmer, Surgeon, Hon. Cur.	4
101	Newcastle-on-Tyne, Northumberland	Castle and Blackgate Ms. of the Antiquarian Society	1813	Robert Blair, F.S.A., Hon. Sec., South Shields	2
102	" "	M. of the Natural History Society, St. James's, Barras Bridge	1829, 1884	Richard Howse, Cur., Museum	1
103	Newport, Isle of Wight	Isle of Wight M., Quay Street	1810, 1852, 1881	John Wood, Hon. Cur., The Cedars, Carisbrooke	3
104	Northampton, Northamptonshire	Northampton M., Guildhall Road	1865	Thomas J. George, F.G.S., Cur., 1 Hazlewood Road	2
105	Northwich, Cheshire	The Brunner Free Public Library and M., Wilton Street	1885	F. A. Howe, Cur., Free Library	4
106	Norwich, Norfolk	Norfolk and Norwich M., St. Andrew's Street	1824	James Reade, Cur., Clarence Road, Thorpe Hamlet	1
107	Nottingham, Nottinghamshire	Free Natural History M., University College	1872, 1881	J. W. Carr, B.A., F.G.S., Cur., University College	1
108	" "	Art M., the Castle	1872, 1878	G. H. Wallis, F.S.A., Director, The Castle	1
109	Oldham, Lancashire	Free Library, M., and Art Gallery, Union Street	1885	Thomas W. Hand, Cur., 169 Windsor Road	3
110	Oxford, Oxfordshire	Bodleian Library and M.	—	G. B. Nicholson, Librarian, Bodleian Library	1
111	" "	University M.	1858	Edward B. Tylor, D.C.L., F.R.S., Keeper	1
112	" "	Ashmolean M.	—	J. H. Parker, C.B., Keeper	1
113	" "	M. of Magdalen College	1868	E. Chapman, F.L.S., Hon. Cur.	4
114	Penrith, Cumberland	Penrith M.	1883	J. Stuart, Librarian	4
115	Penzance, Cornwall	M. of the Royal Geological Society of Cornwall	1814	G. B. Millott, Hon. Sec., Penzance	2
116	" "	M. of Nat. History and Antiquarian Society, Public Buildings	—	John Symons, M.R.C.S., Hon. Cur., Penzance	3
117	" "	The Carne M., Carne, Penzance	1820	Charles C. Ross, Owner, Carne, Penzance	3
118	Peterboro', Northamptonshire	Peterborough M., Minster Close	1886	J. W. Bodger, Hon. Cur., 18 Cowgate	3
119	Plymouth, Devon	M. of Plymouth Institution and Devon and Cornwall Nat. History Society, Athenæum	1829, 1883	J. C. Inglis, Hon. Sec., Athenæum	2
120	Poole, Dorset	Poole M., High Street	1830	W. Penney, A.L.S., Hon. Cur.	4
121	Preston, Lancashire	Free M., Cross Street	1880	Rev. J. Shortt, Hon. Cur., Museum	2
122	Reading, Berks.	Free Public M., Blagrave Street	1883	Joseph Stevens, Hon. Cur.	2

MUSEUMS—*continued.*

Collections		Supported by	No. of Visitors weekly	Duplicates for Exchange	Terms of Admission	Remarks
General	Local					
strial and Fine Art	—	School of Art	—	—	Free daily	Loan from S.K.
., Anth., Zoo., t., Geo.	Geo., Arch., Bot., Zoo., Anth.	Rate . .	1,000	Geo. . .	„	
Zoo., Bot., Arch., th .	—	Local Society	40	Geo., Zoo. .	Free daily	
Zoo., Arch. . .	Geo., Zoo., Bot., Arch.	The College	—	—	Free 1 day	
Zoo., Bot., Arch., th.	—	„ „	—	Geo., Zoo., Bot.	Free 3 days	
strial and Fine Art	—	Subscriptions	2,000	—	Free daily	Open on Sundays, 2 to 5
Zoo., Bot., Arch., th., Industrial and ie Art	—	Rate . .	2,500	Few . .	„	Loan from S.K.
Zoo., Geo., Arch., th.	Bot., Zoo., Geo. .	The College	—	Few . .	Free on application	
Geo., Arch., Anth.	Arch. . . .	Subscriptions and Fees	10	—	6*d.* daily	
Zoo., Bot. . .	—	Rate .	—	Geo. . .	—	Not yet open
—	Geo., Arch. . .	Local Society	Few	—	Free	
., Anth. . . .	Arch., Anth. . .	Local Society and Fees	130	—	6*d.* Castle, 3*d.* Black-gate	
Geo., Zoo., Arch., th.	Bot., Geo., Zoo. .	„ „	350	Geo., Zoo., Bot.	3*d.* daily	
Zoo., Bot., Arch. .	Geo. . .	Local Society	20	Geo. . .	Free daily	
Zoo. . . .	Geo., Zoo., Arch. .	Rate . .	600	Geo., Zoo. .	„	
strial Art . .	—	—	—	—	—	Loan from S. K.
Geo., Bot., Arch., th.	Geo., Zoo., Bot., Arch.	Subscriptions	600	—	Free 2 days	
Geo., Bot., Anth. .	Zoo., Bot., Geo. .	Rate . .	5,500	Zoo. . .	Free 5 days	
., Anth., Industrial l Fine Art	—	Rate and Fees	4,000	—	6*d.* . 1 day, 1*d.* 4 days, Free 1 day	Loan from S. K.
Zoo. . . .	—	Rate . .	—	—	—	Not yet open
(50,000) . .	—	The University	—	—	—	
Zoo., Bot., Anth., dicine	—	„ „	1,000	—	Free daily	
., Anth. . . .	Anth. . . .	Endowment and Fees	20	—	„	
. . . . .	—	The College	—	—	Free on application	
. . . . .	—	Rate . .	—	—	Free daily	
. . . . .	—	Local Society	50	—	Free daily	
Bot., Arch., Anth.	Bot., Zoo. . .	„ „	20	—	„	
ralogy only . .	—	The Owner .	—	—	Free on application	
Zoo., Bot., Arch., th., Engravings	—	Local Society and Fees	10	Geo. . .	6*d.* daily; 1*d.* one night	
Geo., Bot., Anth. .	Geo., Zoo., Bot. .	Local Society	100	Few . .	6*d.* 5 days; free one day	
(few) . . .	Zoo., Geo. . .	„ „	10	—	Free on application	
Zoo., Arch., Anth.	—	Rate . .	400	—	Free daily	
Geo., Zoo., Arch. .	Zoo., Anth. . .	„	1,000	Shells . .	„	

TABLE I.—LIST OF PROV

No.	Town and County	Name and Locality of Museum	Date of Foundation	Name and Address of Curator, Principal Officer, or Owner	Cla-
	ENGLAND—*cont.*				
123	Richmond, Yorks.	M. of Naturalists' Field Club	1885	W. D. Benson, Hon. Cur.	4
124	Ripon, Yorks.	M. of the Naturalists' Club, Park Street	1883	B. M. Smith, Hon. Sec., 31 Princes Road	4
125	Ryde, I. of Wight	Ryde M.	—	B. Barrow, Pres. of School of Science and Art, Ryde	3
126	Saffron Walden, Essex	Saffron Walden M., Museum Street	1832	G. N. Maynard, Cur.	1
127	Salisbury, Wilts.	Salisbury and Blackmore M.	—	—	1
128	Salford, Lancashire	Royal Free M. and Library, Peel Park	1850	Major John Plant, F.G.S., Cur.	1
129	Scarborough, Yorks.	M. of the Philosophical and Archæological Society	1828	J. H. Phillips, Hon. Sec., 22 Albemarle Crescent	2
130	Sheffield, Yorks.	Public M., Weston Park	1875	E. Howarth, F.R.A.S., Holly Bank, Northumberland Road	1
131	Shrewsbury, Shropshire	Free Library and M., Old Grammar School	1885	A. C. Phillips, Libarian, Free Library	2
132	Southampton, Hants	M. of the Hartley Institution	1862	T. W. Shore, F.G.S., Executive Officer, Hartley Institution	1
133	Southport, Lancashire	Botanic Gardens M., Botanic Road, Churchtown	1876	W. Fish, F.R.H.S., Cur., Botanic Gardens	2
134	South Shields, Durham	Free Public M., Ocean Road	1876	L. Inkster, Secretary, Public Library	3
135	Stafford, Staffordshire	The Wragge Free Public M., Free Library	1881	C. J. Calvert, Librarian	3
136	Stalybridge, Lancashire	Park M., Stamford Park	1875	W. Bardsley, Cur., Stamford Park	3
137	Stamford, Lincolnshire	M. of Literary and Scientific Institution, St. Peter's Hill	1842	H. Mitchell, Cur., The Institution	3
138	St. Neots, Huntingdon	Victoria M. The Literary and Scientific Institute	1887	—	4
139	Stockport, Cheshire	Vernon Park M., Vernon Park	1860	John Tym, Cur., The Museum	2
140	Stoke-upon-Trent, Staffordshire	Free Library and M., London Road	1878	Alfred Caddie, Librarian and Cur., Free Libarary	2
141	Stratford-on-Avon, Warwickshire	Shakespeare's Birthplace M., Henley Street	1847	Richard Savage, Secretary, 59 West Street	2
142	Sunderland, Durham	Borough M.	1880	Robert Cameron, Cur., 4 St. Bede's Terrace	1
143	Taunton, Somerset	M. of Archæological and Nat. Hist. Society, Taunton Castle	1849 1875	W. Bidgood, Cur., The Castle	2
144	Torquay, Devon	M. of Natural History Society	—	—	—
145	Truro, Cornwall	M. of the Royal Institution of Cornwall	1818	W. Newcombe, Cur.	2
146	Tynemouth, Northumberland	Free Library and M., Howard Street	1825	G. Tidy, Librarian	3
147	Wakefield, Yorks.	M. of the Naturalists' Society, Westgate	—	W. Rushforth, Hon. Sec., Horbury	4
148	Warrington, Lancashire	Warrington M., Bold Street	1838	Charles Madeley, Cur., The Museum	1
149	Warwick, Warwickshire	Warwick M., Market Square	1836	Rev. P. B. Brodie, F.G.S., Hon. Cur., Vicarage, Rowington	2
150	Watford, Herts	Public Library and M.	1875	Dr. Brett, Hon. Cur.	4
151	Wenlock, Shropshire	Wenlock M., Corn Exchange Buildings	1840	Mrs. S. Landon, Cur.	[illegible]
152	Whitby, Yorks.	M. of the Lit. and Phil. Society, The Pier	1823	Martin Simpson, Cur., Stakesley Vale	[illegible]
153	Winchester	The City M., Guildhall Free Library	1849	J. F. Burchett, Librarian	[illegible]
154	Windsor, Berks.	M. of the Albert Institute	1884	Joseph Lundy, J.P., President, Windsor	[illegible]
155	Wisbech, Cambridgeshire	Wisbech M., Lit. Institution, Museum Square	1835	George Oliver, Cur.	[illegible]
156	Wolverhampton, Staffordshire	Municipal Art Gallery and M., Lichfield Street	1884	W. J. Wheddon, Cur.	[illegible]
157	Woolwich, Kent	Rotunda M., Royal Artillery Institution	—	Major Harman, Sec.	[illegible]

MUSEUMS—*continued.*

Collections — General	Collections — Local	Supported by	No. of Visitors weekly	Duplicates for Exchange	Terms of Admission	Remarks
, Zoo. . . .	—	—	—	—	Small charge	
ı., Geo., Zoo., Bot. .	Arch. . . .	Local Society	10	—	2*d.* daily	
—	Geo., Zoo., Bot. .	Subscriptions	—	—	Free on application	
, Geo., Bot., Arch., ıth., Art	Geo., Arch. . .	Endowment & Subscriptions	200	Geo., Zoo., Bot.	"	
ı., Arch. . . .	—	—	—	—	Free on application	
, Geo., Bot., Arch., ıth.	Zoo., Geo., Bot., Arch., Anth.	Rate . .	7,000	Given away.	Free daily	
, Zoo., Bot., Arch., nth.	—	Local Society and Fees	6,000 in summer	—	3*d.* daily	
., Arch., Zoo., Bot., nth.	—	Rate . .	2,000	Geo. . .	Free daily	
, Zoo., Arch., Geo. .	Arch. . . .	"	—	Few . .	"	
., Zoo., Bot., Arch., nth.	Bot. . . .	Endowment.	500	Geo. . .	Free 5 days	
, Geo., Bot., Arch., nth.	Zoo. . . .	Botanic Gardens Co.	2,500	—	4*d.* daily .	With the gardens
., Geo., Arch. . .	Arch. . . .	Rate . .	1,000	Arch . .	Free daily	
, Geo., Arch., Anth.	—	Rate . .	400	—	Free daily	
., Bot. . . .	Geo. . . .	Endowment and Rate	—	—	Free daily	
., Bot., Arch., Zoo. .	—	Local Society	50	—	6*d.* daily	
., Zoo., Arch., Anth.	—	The Institute	200	—	Free daily	
., Geo., Art . .	—	Rate . .	600	—	Free daily	Loan from S. K.
ustrial and Fine Art	—	"	—	—	"	"
—	Shakespeare Relics	Fees . .	—	—	6*d.* daily .	
., Zoo., Bot., Arch., nth.	Geo. . . .	Rate . .	1,800	Geo., shells	Free daily	
., Zoo., Bot., Arch., nth.	Geo., Arch., Anth.	Local Society	100	—	2*d.* 5 days, 1*d.* 1 day	
—	—	—	—	—	—	
., Geo., Bot., Arch. .	—	Subscriptions	60	Few . .	Free 1 day 6*d.* 5 days	
., Zoo., Bot., Arch. .	—	Rate . .	200	—	Free 1 day	
., Bot., Geo. . .	—	Local Society	—	—	—	Only open on special occasions
., Arch., Geo., Bot., rt, Anth.	Arch. . . .	Rate . .	600	Shells . .	Free 3 days	Loan from S.K.
., Zoo., Bot., Arch., nth.	Geo. . . .	Subscriptions	100	Geo., shells .	Free 2 days	
., Geo., Art, Anth. .	Bot., Geo., Zoo ..	Local Society	Few	—	Free daily	Loan S. K.
., Arch., Bot. . .	Geo. . . .	Subscriptions	30	Geo. . .	Free daily	
., Bot., Zoo., Arch. .	Geo., Zoo. . .	Local Society and Fees	30	—	6*d.* daily	
., Zoo., Arch. . .	—	Rate . .	100	—	Free daily	
., Zoo., Arch., Anth., nd. Art	—	The Institution	—	—	Free on application	
o., Arch., Bot., Zoo., nth., Art	Geo., Zoo., Arch. .	Endowment and Subscriptions	Few	—	6*d.* daily	
lustrial and Fine Art	—	Rate . .	700	—	Free daily	
ms and Trophies .	—	Government	—	—	"	

TABLE I.—LIST OF PROVI

No.	Town and County	Name and Locality of Museum	Date of Foundation	Name and Address of Curator, Principal Officer, or Owner	Class
	ENGLAND—*cont.*				
158	Worcester, Worcestershire	The Hastings M., Public Library	1837	George Reece, Cur. . . .	2
159	York, Yorks. . .	M. of Yorkshire Phil. Society . .	—	H. M. Platnauer, Cur., Low Royd, St. Olave's Road	1
	SCOTLAND *—				
160	Edinburgh, Mid-Lothian	M. of Science and Art, Chambers Street	1854	Colonel R. M. Smith, R.E., Director	1
161	" "	National M. of Antiquities, Princes Street	1780, 1859	Joseph Anderson, LL.D., Keeper .	1
162	Aberdeen, Aberdeenshire	University M.	—	Prof. H. A. Nicholson, M.D., Director	2
163	Abbotsford, Roxburghshire	The Abbotsford M. . . .	—	Hon. Mrs. Maxwell Scott, Owner, Abbotsford	2
164	Alloa, Clackmannan	M. of the Society of Nat. Science and Archæology, Church Street	1863	J. Ferguson Lyon, Hon. Cur., Greenfield Place	3
165	Banff, Banffshire .	Banff M.	1828 1875	James Watt, Hon. Sec. . . .	3
166	Dumfries, Dumfriesshire	The Observatory M. . . .	1835	P. Dudgeon, Chairman, Cargen .	3
167	" "	M. of Nat. Hist. and Antiquarian Society, Church Crescent	1885	J. Wilson, Hon. Sec., 3 Norfolk Terrace	4
168	Dundee, Forfarshire	Albert Institute M. . . .	1873	John MacLauchlan, Cur. . .	1
169	" "	University College M. . . .	1885	Prof. D'Arcy Thompson, B.A., Cur.	3
170	Elgin, Elgin . .	Elgin M., High Street . . .	1836	John Gatherer, Cur. . . .	2
171	Forres, Elgin .	Falconer M., Tolbooth Street .	1871	J. D. Davidson, Secretary, Forres	4
172	Glasgow, Lanarkshire	The Hunterian M., The University	—	Prof. J. Young, M.D., Cur. . .	1
173	" "	Anderson College M. . . .	—	—	2
174	" "	Kelvingrove M.	1870	James Paton, F.L.S., Cur. . .	1
175	" "	M. of Geol. Society . . .	—	—	3
176	Greenock, Renfrewshire	Greenock M.	1875	W. F. Dunlop, Cur. . . .	2
177	Hawick, Roxburghshire	M. of the Archæolog. Soc., Buccleugh Memorial Building	—	D. Watson, Treasurer . . .	3
178	Inverness, Inverness-shire	—	—	—	—
179	Kelso, Roxburghshire	M. of Tweedside Physical and Antiquarian Society, Roxburgh Street	1833	Edward Johnson, Secretary, Tweed Bank	3
180	Kilmarnock . .	Burns' Monument M. . . .	—	—	—
181	Kirkcudbright, Kirkcudbrightshire	Kirkcudbright M., Town Hall .	1881	Geo. Hamilton, Hon. Sec. . .	3
182	Largo, Fifeshire .	M. of Field Naturalists' Society .	1863	E. Kennedy, Sec., Bayview . .	3
183	Montrose, Forfarshire	M. of the Nat. History and Antiquarian Society	1837	Robert Barclay, Hon. Sec. . .	2
184	Paisley, Renfrewshire	Free Library and M., High Street	1871	Morris Young, F.E.S., Cur., The Museum	1
185	Perth, Perthshire .	M. of Literary and Antiquarian Society, George Street	1785	A. R. Urquhart, M.D., Hon. Sec. .	2
186	" "	M. of Society of Natural Science, Tay Street	—	—	—

* The Museums of Edinburgh and Dublin, being Metropolitan Institutions, ar

, MUSEUMS—*continued.*

Collections		Supported by	No. of Visitors weekly	Duplicates for Exchange	Terms of Admission	Remarks
General	Local					
, Geo., Bot., Arch., nth.	Geo., Zoo., Bot., Arch.	Rate	—	—	Free daily	
.., Zoo., Bot., Arch., nth.	Geo., Arch.	Local Society	500	Geo.	1*s.* daily	
.., Zoo., Ind. Art, rch., Anth.	—	Government	7,000	Few	Free 3 days; 6*d.* 3 days	
h., Anth.	Arch., Anth	Endowment	2,000	—	Free 3½ days; 6*d.* 2½ days	
., Bot.		The University	—	—	Free one day	
our and Antiquities	—	The Owner and Fees	—	—	1*s.* daily	
., Geo., Bot., Arch., nth.	—	Local Society	—	—	Small charge daily	
., Zoo., Anth.	Geo., Zoo., Anth.	Fees	20	—	6*d.* 3 days, 3*d.* 3 days	
., Zoo., Arch., Anth.	Geo., Zoo., Arch.	Subscriptions and Fees	150	—	6*d.* 5 days, 3*d.* 1 day	
—	Bot., Geo., Zoo., Arch.	Local Society	—	Few	Free on application	
., Geo., Bot., Arch., nth.	Zoo., Geo., Bot.	Rate	5,000	Few	Free daily	Art Gallery included
., Bot.	—	The College	—	Few	Free on application	For teaching only
., Geo., Arch., Anth.	Geo., Zoo., Bot.	Local Society and Fees	20	—	6*d.* daily	
., Zoo., Bot., Arch.	Zoo., Bot., Arch.	Endowment and Fees	10	—	6*d.* daily	
h., Geo., Zoo., Bot.	—	The University	—	—	6*d.* daily	
., Zoo., Bot.	—	The College	—	—	—	Collections packed away
., Geo., Bot., Arch.	Zoo., Bot.	Rate	4,000	—	Free daily	
—	Geo.	Local Society	—	—	—	Collections packed away
—	—	Endowment	250	—	Free daily	
., Zoo., Arch.	—	Local Society and Fees	—	—	2*d.* 1 day.	
—	—	—	—	—	—	
., Zoo., Geo., Arch.	—	Local Society	—	—	—	
—	—	—	—	—	Small charge	
., Arch., Bot., Geo., d. Art	Bot., Zoo., Arch.	Subscriptions and Fees	25	Geo., Zoo.	6*d.* daily	Loan from S.K.
., Zoo., Arch.	Geo., Zoo., Bot., Arch.	Local Society	5	—	Free daily	
., Zoo., Bot., Arch., nth.	Geo., Zoo., Bot.	Local Society and Fees	—	Geo., Zoo.	6*d.* daily; working class 1*d.*	
., Arch., Geo., Bot., nth., Ind. Art	—	Rate	900	Zoo.	Free daily	Loan from S.K.
., Zoo., Bot., Arch., nth.	Zoo.	Local Society	38	—	—	
—	—	—	—	—	—	—

d at the heads of their respective columns, not in the alphabetical arrangement.

TABLE I.—LIST OF PROV

No.	Town and County	Name and Locality of Museum	Date of Foundation	Name and Address of Curator, Principal Officer, or Owner	Clas[s]
	SCOTLAND—*cont.*				
187	Peterhead, Aberdeenshire	Arbuthnot M., Chapel Street	1851	James Aiken, Hon. Cur., 11 Jamaica Street	3
188	St. Andrews, Fifeshire	University M.	15th century, 1837	Thomas Walker, Cur., The Museum	1
189	Stirling, Stirlingshire	Stirling M., Smith Institute . .	1874	James Sword, Cur., Smith Institute	3
190	Thornhill, Dumfriesshire	Thornhill M., New Street . .	1872	T. B. Grierson, M.D., Owner . .	2
	IRELAND—				
191	Dublin, Dublin .	Science and Art M., Kildare Street	—	Prof. V. Ball, M.A., F.R.S., Director	1
192	„ „ .	M. of Royal College of Science .	—	Prof. A. C. Haddon, Cur. . .	2
193	„ „ .	M. of Geology, Trinity College .	—	—	—
194	„ „	M. of Anatomy and Zoology, Trinity College	1777	H. W. Macintosh, Cur., School of Physic, Trinity College	1
195	„ „	Herbarium, Trinity College . .	—	Dr. E. P. Wright, Keeper . .	1
196	„ „	M. of Royal Irish Academy, 19 Dawson Street	1786	Major R. MacEniry, Cur., 19 Dawson Street	1
197	„ „	M. of Royal College of Surgeons, Stephen's Green	1789, 1820	A. B. McKee, M.B., Royal College of Surgeons	1
198	Armagh, Armagh .	M. of Nat. History and Philosophical Society, The Mall	1851	G. R. Johnson, Hon. Sec., The College	3
199	Belfast, Antrim .	Belfast M., College Square, North.	1821, 1831	W. Darragh, Cur., The Museum .	1
200	„ „ .	M. of Queen's College . . .	1847	R. O. Cunningham, M.D., Cur., 17 College Gardens	2
201	Cork, Cork . .	M. of Queen's College . . .	1851	Professor Marcus M. Hartog, Cur., The College	1
202	Galway, Galway .	M. of Queen's College . . .	1849	R. J. Anderson, Cur., The College	2
203	Kilkenny, Kilkenny	M. of Royal Historical and Archæological Society of Ireland	1849	J. G. Robertson, Hon. Cur. . .	3
	WALES—				
204	Aberystwith, Cardiganshire	M. of University College . .	1874	—	3
205	Bangor, Carnarvonshire	M. and Reading Room . . .	1873	Peter Williams, Cur. . . .	3
206	Cardiff, Glamorganshire	Free M., Trinity Street . . .	1867, 1883	John Stoorie, Cur., 6 Queen's Place, Crockherbtown	1
207	Carnarvon, Carnarvonshire	—	—	—	1
208	Neath, Glamorganshire	M. of Mechanics' Inst. . . .	—	—	4
209	Swansea, Glamorganshire	M. of the Royal Institution of S. Wales	1835, 1883	Hort. Huxham, Hon. Sec., Swansea	1
210	Tenby, Pembroke .	Local M., The Castle . . .	1878	E. Lawes, Hon. Sec. . . .	3
211	Welshpool, Montgomeryshire	Powys-Land M. and Library and School of Art, Salop Road	1874	Morris C. Jones, F.S.A., Hon. Cur., Gungrog Hall	2

MUSEUMS—*continued.*

Collections: General	Collections: Local	Supported by	No. of Visitors weekly	Duplicates for Exchange	Terms of Admission	Remarks
Arch., Geo., Bot., th.	—	Boro' Fund and Fees	20	—	2*d.* daily	
Zoo., Bot., Arch., th.	Zoo., Marine Laboratory	University and Local Society	—	Marine Zoo.,	Free daily	
Zoo., Bot., Arch., h.	Zoo. . . .	Endowment .	100	—	"	
Geo., Bot., Arch., h.	Arch., Anth. . .	The Owner .	20	—	6*d.* daily	
Zoo., Bot., Arch., h., Ind. Art	Geo., Zoo. . .	Government .	4,000	Geo., Zoo., Bot	Free daily	Open on Sunday. Loan from S.K.
rt, Geo., Zoo., Bot.	—	Government .	—	—	"	—
—	—	The College .	—	—	—	
Comp. Anatomy .	—	The College .	—	Few . .	Free daily	
. . . . .	—	The College .	—	—	"	
—	Arch., Anth. . .	The Academy and Government	—	—	"	
ry	—	The College .	50	Pathology .	Free on application	
eo., Bot., Arch. .	Zoo. .	Local Society	—	Geo., Zoo. .	Free daily	
Arch., Bot., Geo., h.	Geo., Zoo. rch., Bot.	Local Society and Fees	25	Geo., Zoo., Bot.	6*d.* daily	
oo., Bot. . .	—	The College .	—	Geo., Zoo., Bot.	Free on application	
eo., Zoo., Arch., h.	Geo., Zoo., Bot. .	" "	—	Geo. . .	Free daily	
Zoo., Bot. Arch., h.	Geo. . . .	" "	—	—	"	
Anth. . .	Arch., Anth. . .	Subscriptions	Few	—	Free on application	
Zoo., Bot., Arch., Art	Geo., Zoo., Bot. .	The College	—	—	Free on application	Lately burnt down
oo., Arch., Anth.	—	Rate . .	—	—	Free daily	
oo., Bot., Arch., and Fine Art	Zoo., Bot., Arch. .	" "	—	—	Free five days	Loan from S. K.
rial Art . .	—	—	—	—	—	
Geo. . . .	—	The Institute	—	—	—	
Zoo., Bot., Arch., ., Ind. Art	—	Subscriptions and Fees	250	Few . .	1*d.* daily	
—	Geo., Zoo., Bot., Anth.	Subscriptions and Fees	20	—	6*d.* daily	
rch., Geo., Bot. .	Zoo., Bot. . .	Local Society and Fees	Few	Shells .	3*d.* daily	

TABLE II.

Approximate Estimate of the Number of Specimens contained in the Provincial Museums.

Collections	Geology	Zoology	Botany	Archæology	Anthropology	Sundries	Art
General	2,000,000	1,000,000	500,000	250,000	50,000	50,000	20,000
Local	200,000	100,000	20,000	100,000	5,000	5,000	—
Loan	10,000	5,000	5,000	3,000	1,000	1,000	15,000
	2,210,000	1,105,000	525,000	353,000	56,000	56,000	35,000

Number of Museums estimated as First class	56
" " " Second class	55
" " " Third class	63
" " " Fourth class	30
	204
No information	7
	211

Museums consisting entirely of General Collections	95
" " entirely or chiefly of Local Collections	16
" " of both Local and General Collections	92
	203
No information	8
	211

Museums in which the largest Collections are Geological	98
" " " Zoological	49
" " " Botanical	9
" " " Archæological	23
" " " Art	16
Miscellaneous and not sufficiently reported	16
	211

Provincial Museums in England	159
" " Scotland	31
" " Ireland	13
" " Wales	8
	211

Provincial Museums supported by Special Rate	50
" " " General Borough Funds	5
" " " Local Societies	50
" " " Local Institutions	13
" " " Annual Subscriptions	21
" " " Colleges	30
" " " Government	8
" " " Private Owners	11
" " " Endowment	11
" " " Unknown	12
	211

Museums Free to the Public daily	84
" " " on certain days only	15
" Charging Entrance Fees daily, from 1*d.* to 1*s.*	46
" " " on certain days only	8
" Free on Special Order or Application	31
" Open on Sunday	4
" Receiving Loans from South Kensington	19

TABLE III.

List of Collections of Special or Local Interest which are distributed about the country, with the Museums in which they are preserved.

This list might probably be greatly extended. Many Museums did not make any return of their special collections.

Geology.

Collection of Agostino Scilla, 1670	Cambridge, Woodwardian M.
" Dr. Woodward, 1695–1727	" "
" Barrande	" "
" Forbes Young	" "
" Fletcher	" "
" Leckenby	" "
" Walton	" "
" Montagu Smith	" "
" Dr. Daubeney	Oxford, Magdalen College.
" Dr. Grindrod	" University M.
" Professor Harkness	Carlisle.
" Clifton Ward	"
" Traill	Liverpool, Royal Institute.
Geology of the Fens	Wisbech.
" Yorkshire	York.
" East Yorkshire	Scarborough.
" Ireland	Dublin.
" West Ireland	Galway.
" Ulster	Belfast.
" Isle of Wight	Newport.
" Somerset	Bath.
Fossils of Palæozoic and Mesozoic Strata	Eastbourne; Dudley.
" Permian	Sunderland.
" Jurassic	Middlesborough.
" Chalk (Willett)	Brighton.
" Upper Chalk, Crag, and Drift	Saffron Walden.
" Trias	Warwick.
" Hampshire Basin Tertiaries	Southampton.
" Coal	Newcastle Nat. Hist.; Stalybridge; Liverpool Free M.; Chesterfield.
" Dorsetshire	Dorchester.
" Skiddaw Slates (Harrison)	Keswick.
" Greensand (Griffiths)	Brighton.
" Paris Basin (Davidson)	"
" Lias	Leicester; Whitby; Warwick.
" Post-glacial deposits	Liverpool, Free M.
" Old Red Sandstone (Altyre)	Forres.
Minerals, fine collections	Truro; Devonport; Montrose.
" Carne collection	Penzance.
" Keate collection	Giggleswick.
Agates, India, &c.	Eastbourne.
Scotch pebbles, unique	Montrose.

Cave remains, Victoria Cave	Giggleswick.
„ Creswell Caves	Derby.
„ Mendip Hills	Taunton.
„ Kent's Cavern	Torquay.

ZOOLOGY.

Mammalia, pictorially mounted	Liverpool Free M.; Leicester.
„ of Ireland	Dublin.
„ of Ulster	Belfast.
„ of Munster	Cork.
„ Elephas primigenius, from Siberia	Cheltenham.
Birds, British, nearly complete	Leeds; Leicester; Durham; Sunderland; Coalbrookdale; Devizes; Wisbech; Elgin; Brighton Dyke Road M.; Scarboro'.
„ Hancock collection	Newcastle, N. H. Society.
„ Raptorial (Gurney)	Norwich.
„ of Kent (Hornby)	Dover.
„ of Devon	Exeter, Plymouth.
„ of the Tay Valley	Dundee.
„ Gurney collection	King's Lynn.
„ the extinct Great Auk	Norwich.
„ European, skins	Leeds.
„ of Ceylon (Lord Wimborne)	Poole.
„ British, skeletons (Strickland)	Worcester.
„ of New Guinea (Stone)	Leicester.
„ Skeletons of extinct Moa	Manchester, Owens College.
Fish, British	Wisbech.
„ Australian, Ceratodi	Bristol.
„ development of the salmon	Perth.
Invertebrates, fine collection	Liverpool Free M.; Nottingham.
„ European, Coleoptera	Bootle.
„ Ireland	Dublin; Belfast; Cork.
„ of the Tay Valley	Dundee.
„ Lancashire insects (Gibson)	Salford.
„ British Lepidoptera (Cooke)	Liverpool.
„ of Devon	Plymouth.
„ recent shells, foreign (Sir G. Whitmore)	Worcester.
„ recent shells	Stockport.
„ „ British	Wisbech.
Marine fauna	St. Andrews; Liverpool College.
Teeth	Cirencester
Injurious insects	Huddersfield.

BOTANY.

British herbaria	Dublin (T. Coll.); Cork; Cambridge; Thornhill; Norwich; Nottingham.
Flora of Hampshire	Southampton.
„ Hertfordshire	Watford.
„ Isle of Wight	Ryde.
„ Somerset, &c. (Blomefield)	Bath.
Balfour Botanical collection	Perth.
Mosses of Cornwall (Curnow)	Penzance.
Flora of Cape of Good Hope (Flora Capensis)	Dublin, Trinity Coll.
Freshwater Algæ (Bates)	Leicester.

ARCHÆOLOGY.

Roman, from Wilderspool	Warrington.
„ „ Eboracum	York.

Roman, from Isurium	Aldborough, Yorks.
„ „ Hampshire	Andover.
„ „ Bath	Bath.
„ „ Chester	Chester.
„ „ Vinorium	Durham.
„ „ Ratæ	Leicester.
„ „ North of England	Newcastle; Carlisle.
„ „ Ripon	Ripon.
„ „ Uriconium	Shrewsbury.
„ „ South Shields	South Shields.
Irish antiquities, especially gold ornaments	Dublin, R. I. Academy.
Scotch „	Edinburgh, R. Institution.
Kentish „	Maidstone.
Glastonbury „	Glastonbury.
Dorset „	Dorchester.
Forfarshire „ sculptured stones	Montrose.
General British to Mediæval	Wisbech; Devizes; Sheffield.
Egyptian	Bristol; Alnwick.
Disney marbles	Cambridge, Fitzwilliam M.
Central American sculpture (Maudsley)	„ „
Coins (Leake)	„ „
„ British silver	Marlborough College.
„ very large collection	Oxford, Bodleian.

Anthropology.

The Pitt-Rivers collection	Oxford.
Stapenhill „	Burton-on-Trent.
General „ large	Liverpool, R. Inst. M.
Pre-historic „	Exeter; Eton; York; Cheltenham; Preston; Reading; Scarborough; Manchester, Owens College.
Mummies, unrolled	Brighton.
„ Peruvian	Haslar Hospital.
Pacific Islands	Cambridge, Fitzwilliam M.
Indian and Chinese	Newcastle, Blackgate M.
Cyprian pottery (Anderson)	Dumfries, Observatory M
Anglian cinerary urns	York.
Military weapons	Woolwich.
Unique amber cup, from a barrow	Brighton.
Musical instruments	Manchester, Queen's Pk. M.
Shakespeare relics	Stratford-on-Avon.
Bewick „	Newcastle, Nat. Hist. M.
Walter Scott „	Abbotsford.

Miscellaneous.

The Mayer collection of historical art treasures (very fine)	Liverpool, Free M.
Silk production, breeding, manufacture, &c.	Nottingham.
Food materials	Manchester, Queen's Pk. M.
Comparative anatomy	Dublin, Trin. Coll. M.
Pathology	„ „ and Leeds.
Pictures of buildings and scenery round Manchester	Manchester, Ancoats Hall M.

4. Discussion of Details.

The questions in Schedule B are here taken seriatim.

Note.—In the references to various groups of museums in the following pages the numbers given are not absolutely accurate, owing to the incompleteness of the statistics.

1, 2, 3, 4. *Foundation, Ownership, Support and Government.*—About one-half of the existing museums of the country were originated by local

societies, and one-half of these have been since handed over either to municipal corporations or to bodies of trustees for the benefit of the public, the remainder being still the property of the local societies.

About one-fourth of the existing museums were originated by individual collectors, but only about a dozen of these remain in private hands. About 55 museums are now the property of municipal corporations, and are nearly all supported by local rates levied under the Public Libraries Act.

About thirty belong to public institutions, universities, or schools, and are supported by those institutions or by Government grants. About half a dozen belong to and are entirely supported by the Imperial Government. About a dozen museums were established prior to the beginning of this century, about 100 were established between 1800 and 1870, and nearly 100 have been opened during the last sixteen years.

The Public Libraries Act requires that the public shall have free admission to all institutions, libraries, museums, or art galleries established under its authority. In a Bill introduced to amend the Act, a few years ago, it was proposed to modify this clause, giving corporations power to make a charge on certain days, and also to raise the maximum rate from a penny to twopence. This Bill, however, has not been passed. Several towns have obtained power to levy a twopenny rate by clauses inserted in their local Acts.

The charges for admission to museums which are not rate-supported vary from one penny to one shilling. Frequently the charge for two persons or for a party is on a reduced scale, and schools and children are often admitted at a still lower price.

The usual amount realised by entrance-fees varies from 5*l.* to 100*l.* per annum. A very few museums obtain 150*l.* or 200*l.* from this source. There are four whose receipts from fees are probably from 500*l.* to 1,000*l.* a year, viz., Nottingham Art Museum, York, Scarborough, and Southport. In all these cases the pictures and the gardens are additional attractions.

5. *Cost of Maintenance.*—In a large proportion of the municipal museums the cost of maintenance is mixed up with that of a free library or an art gallery, and cannot be separately stated. It appears, however, that no first-class public museum while in a growing condition can be efficiently conducted for less than about 800*l.* a year, and that the very large national museums in Edinburgh and Dublin cost about 10,000*l.* a year each.

Second-class museums may be taken to cost from 100*l.* to 500*l* a year; third-class from 25*l.* to 100*l.*; fourth-class museums are mostly in a neglected condition, and the money spent upon them is trifling.

6. *Staff and Hours.*—A first-class museum requires at least 1 curator at a minimum salary of 150*l.*, 1 assistant curator at a minimum salary of 30*l.*, and 2 caretakers or workpeople at a minimum salary of 25*l.* each.

The large science and art museums in Edinburgh and Dublin have each 1 director, 7 curators and assistants, about 30 porters and workpeople, including women, and pay 5,000*l.* a year each in salaries.

A second-class museum has usually a salaried curator, and a workman or caretaker.

Third and fourth class museums have frequently only a caretaker.

In addition to the paid officers, however, there is a large amount of supervision, and of actual work done in provincial museums by honorary curators, especially in the second, third, and fourth classes.

First-class museums, being more efficiently officered, do not require so much outside assistance, and in many cases the position of the curator is such that he could not submit to the supervision of an amateur.

Where the museum is in connection with a free library, the two offices of librarian and curator are frequently combined. This may be an economy, but it is rarely satisfactory for the museum. The library is usually regarded as the more important institution; the officer is chosen as a librarian chiefly, the larger proportion of space and funds are devoted to the library, and the museum is not conducted with the necessary vigour, and often falls into disrepute. On the other hand, there is considerable advantage in having the two institutions under the same roof, as the library is then available for the staff and the students of the museum, and the museum is as a book of plates close at hand to illustrate the volumes in the library.

Museums belonging to local societies are often without any paid staff or even an attendant, the whole work being performed by members, but with the regular admission of the public comes, of course, the necessity of regular and therefore of paid attendance.

Rate-supported museums are generally open to the public five or six days a week. It is necessary to close them at intervals for cleaning, and there is much variation in the arrangements made for this purpose. Some museums take two days quarterly, some one day monthly or weekly, some open later in the morning and get the cleaning done day by day without closing, some close one room at a time only, others open only four days a week for the general public and two days for students, and most of the cleaning can be done on the comparatively quiet students' days.

The usual hours of opening are from 10 till dusk if the museum has no artificial light, from 10 till 8 or 9 if there is gas. The longest hours are reported from Canterbury, where the museum is open from 9 A.M. till 10 P.M. In museums belonging to local societies the hours vary greatly, many being only open to the public on two or three afternoons weekly. Malvern College admits the public to its museum for two hours only on Thursdays; but generally in these semi-private museums admission may be obtained by special application. In first-class museums the staff are generally in attendance for an hour or two before the time of opening to the public, and where the museum belongs to the corporation, one or two policemen are frequently on duty either all day or at certain hours, in addition to the regular staff. The bye-laws of some museums authorise the curator to exclude young children either altogether or except in proper charge.

From Birmingham comes a suggestion that the staff of every large museum ought to be regularly drilled as a fire-brigade.

7. *Tenure of Buildings.*—The great majority of provincial museums of all kinds are lodged in freehold buildings, about twenty hold their premises on lease and twenty as annual tenants, nearly the whole of these museums being the property of societies or individuals. In only two reported instances are rate-supported museums kept in rented buildings, and in these the arrangement is not intended to be permanent.

8. *Superficial Area.*—There is some difference of opinion as to the respective advantages of large halls and of rooms of moderate size for museum purposes. Museums have been erected on both systems. In the majority of the newer buildings the large-hall system has been adopted,

often surrounded by one or two tiers of galleries, each affording as much wall space and about half as much floor space as the hall itself. One objection to galleries is that they obstruct the light on the walls, and the remedy for this is to pierce the walls with windows, and to place the cases at right angles to the wall instead of flat against it. In the small-room system the principal rooms vary in size from about 30×17 to about 60×25. In the large-hall system the principal halls run from about 60×30 to about 250×70. A first-class museum must have at least 5,000 square feet of floor space. The majority of these have from 5,000 to 10,000, a few have between 10,000 and 50,000, and the Edinburgh Museum of Science and Art provides 100,000 square feet, including the galleries.

Second-class museums have generally from 2,500 to 5,000 feet of superficial area, third-class from 1,000 to 2,000, and fourth-class from 250 to 750.

For the lighting of the rooms by day a top-light is generally preferred where it can be got, but in buildings of more than one storey side lights are inevitable on the lower floors. In a few modern museums, built in ornate Gothic style, the windows come within a few feet of the ground, and have their heads filled with heavy tracery, thus supplying light under the worst possible conditions. There can scarcely be too much light in a museum room, especially in the upper part, but it is desirable to exclude direct sunshine, as it rapidly destroys the colours of organic objects. Side windows should, therefore, be placed in north walls wherever this is practicable.

For lighting by night, gas is of course the usual means. Several museums have adopted the Wenham light, and several of the larger ones are lighted by electricity, as at Birmingham, Leeds, and Brighton. There can be no doubt that the fumes of open gaslights are injurious to many objects. 'Sun-lights' get rid of the fumes, but being near to the ceiling, and thus as far as possible from the cases, the waste of light is very large. The Wenham light can be suspended at any distance from the ceiling, and the fumes are conducted away, but this burner is liable to be blown out or much disturbed by a down draft, and moreover the light is too concentrated, and casts black shadows. Doubtless, for museum purposes, the electric incandescent light is the best, but there is some hope that the new incandescent gas-light may prove to be a valuable substitute.

For warming museums a number of different systems are in use, viz., open fires, coal and gas stoves of various designs, hot air, and hot water. For small rooms open fires have some advantages, particularly in securing ventilation. Gas stoves are now made to condense the whole products of combustion; thus they require no chimney, and are useful auxiliaries. Hot-water pipes are too often hidden under cases and desks, and their heating power minimised. It may be good for the cases to be kept warm and dry, but extra power must be provided if the air of the room is also to be efficiently warmed. Coils of hot-water pipes standing out in the rooms away from the walls are as effective as anything.

The ventilation of rooms in which many persons congregate is often very troublesome. Tobin ventilators are good, but quite useless unless a rapid *egress* of air from the room is first secured, and many methods which are supposed to secure this fail in practice. In lighting a museum either by day or night it is most important to arrange the incidence of the light so that the source of it shall not be reflected from the glazed cases to the eyes of the visitors.

9. *Cases.*—Vertical wall-cases and horizontal table-cases are used in all museums. Some have also upright detached cases glazed all round, and some have upright pillars, from which glazed frames project, hinged to the pillar, and movable like the leaves of a book. These are good for photographs, engravings, textile fabrics, &c., or for dried plants, and even for insects. Vertical wall-cases should not be more than eight or nine feet high; a division into bays of about five feet wide is convenient. These should be glazed with plate glass, either in one sheet or divided by narrow strips of wood or metal horizontally into two or three squares, the divisions corresponding with the edges of shelving inside. Drawers should be provided under all the horizontal table-cases, but should not come quite to the ground, unless they are recessed, otherwise they are in the way of the feet of visitors. Table-cases are often made with an upright glazed compartment along the centre. This gives additional space, but interferes somewhat with the view of objects beneath it. Whether it is better to run the wall-cases round the room with their backs to the wall, or to have side windows and cases between them projecting from the wall at right angles, is still an open question. The latter arrangement does not show the classification so clearly to the eye, and does not favour an easy circulation of visitors, but it may sometimes afford better light and more space.

10. *Dust.*—The exclusion of dust from the cases is a very important matter in all museums. Most of the older cases are very defective on this point, but those more recently built have all joints deeply rabbeted and lined with cloth, velvet, rubber, or cotton-wool, and all the lids and doors closely screwed up with some special kind of screw. Some paste paper over all the joints. At Nottingham a small tin gutter runs under the joint to catch any dust which may get through. The Birmingham Museum and Art Gallery finds a 'double rabbet' successful. From Norwich 'Brown's Patent' is reported to have stood sound for fifteen years. This consists of a hollow tube of cloth. The Rev. H. H. Higgins, of Liverpool, who has had much experience, says that nothing will absolutely exclude dust in a public museum where hundreds or thousands of visitors tramp over the floors daily, but that the objects must be tenderly dusted by hand at short intervals.

11. *Fittings.*—These are made of various woods and in various colours. In the best museums plain oak, polished mahogany, or ebonised baywood are generally used. Ebonised wood has a handsome appearance, and is not obtrusive, but is undesirable for table-cases, as the stain wears off by friction. Polished mahogany is handsome and durable, but has perhaps too heavy an appearance. Plain oak, neither coloured nor varnished, is cheerful and wears well. In small museums birch and deal stained, varnished, or painted, are used for the sake of economy. For shelving within the cases plate-glass is now much used, as it makes less shadow than opaque material. Many experiments have been tried in the internal colouring and lining of the cases. At Liverpool a rich dark blue has been found effective as a background in the wall-cases. Other museums line with white or tinted paper. For archæological and art specimens the cases are often lined with cloth of various hues—maroon, olive green, Turkey red, &c. As the natural history collections come more and more to be set up pictorially the difficulty will disappear in their cases, as the backgrounds will form part of each pictorial group.

The best museums have many ingenious devices contrived by their own officers, such as special fasteners for the cases, supports for open lids, blinds for protection from light, stands for specimens and labels, cements, &c. At Brighton some cases full of very valuable objects are protected by electric alarms. At Montrose coins are exhibited in locked cases, through which run a number of narrow wire frames turning on pins which project through the sides of the case. On these frames the coins with their labels are fastened, and thus both sides are readily seen. At Peterhead the coins are mounted in circular holes cut out of sheets of cardboard which are glazed on both sides. These glazed sheets are kept in a cabinet. At the Dublin Museum of Anatomy osteological specimens are mounted in revolving spindles, so that students may examine every part. The Cork Museum reports that 'slit gun-barrel has been largely used for the insertion of stands, &c.' Fragile objects are exhibited in glass-topped boxes of various sizes, from the small pill-box upwards; these are often partly filled with cotton-wool. Shallow glazed drawers are frequently used for the exhibition of insects, eggs, &c., which are injured by light. They are thus much better protected than in table-cases, even with blinds over them, as the blinds are removed by visitors and frequently not replaced. The glazed drawers can be drawn out by the public, but a stop prevents them from being removed, and each drawer is locked. This system saves much space.

12. *Methods of Preservation.*—Camphor is the usual preservative against moths, and is effectual if freely supplied. At King's Lynn pure carbolic acid on cotton-wool is found entirely to prevent mould in the insect-cases. The vapour of benzine seems to be of much value in the cases of stuffed animals. At Bolton bird-skins are cured with three parts burnt alum and one part saltpetre, and washed inside with a solution of mercuric chloride. The plumage is also washed with a very weak solution of the same. At Aston Hall, Birmingham, all natural history specimens are preserved by a private chemical process. At Cirencester iron antiquities are soaked in very hot white paraffin. In the medical department of the Yorkshire College many delicate pathological specimens are preserved in glycerine jelly.

At Leicester modelling is largely used. A new method of modelling fish has been introduced which is light, of good texture, and takes colour better than a plaster cast. Many museums have collections of Blaschka's glass models of invertebrates, and of opaque white models of foraminifera on a magnified scale. Fossils, shells, &c., are commonly fastened to tablets made of wood or thick millboard or plate-glass and covered with tinted paper. Cements of various kinds are used, but these often fail, and after a time the specimens get loose. At York fine wire is preferred. At Liverpool many specimens are kept in their places by several short pins only, and these may be so arranged as to lift small specimens nearer to the eye. At Owens College, Manchester, recent shells are laid on a bed of fine sand, which has a natural appearance and holds them in place. A workshop for the curator and his assistants is an essential feature in all good museums.

13 and 14. *Mounting.*—The teaching power of natural history specimens depends very largely upon the manner in which they are placed before the eye. A single bird stuffed in an unnatural position teaches very little. Well stuffed it teaches a good deal more, even though it stand alone on a mere wooden peg. A family group of birds, comprising

the male and female, the young in several stages, the nest and eggs, set up with their natural surroundings of plants, stones, water, &c., the nest in its natural position, the birds in the usual attitudes of active life, feeding, building, &c., teaches more than can be learnt from books or even from the casual observation of nature. This fact is now beginning to be recognised, and many museums are making small attempts in this direction. But it is a slow and costly process to reconstruct a collection which has been formed on the old-fashioned plan. At Leicester this has been done, however, to some extent, and a striking effect is produced. But as the object in this case was rather to attract than to teach, the result is disappointing. An attempt has been made to illustrate the vertebrate fauna of the whole world in a range of wall-cases scarcely 200 feet long, and this is done simply by setting up single specimens of a few forms in each order with pictorial surroundings. The scenery is cleverly constructed, and shows some of the habits of a few species. It is unfortunate that it was not started on a better principle. A less ambitious attempt more thoroughly worked out would be far more valuable. A collection of local birds is now being got together at Leicester, and a somewhat better system is adopted. A family group of each species is represented, but at present the great teaching value of *comparison* is ignored. At the Natural History Museum at South Kensington the same mistake is made. Family groups excellently set up in separate cases are placed at a distance from each other and from all related forms. They would teach more if they were less isolated, and if there were single specimens of foreign allied types close at hand for comparison. The value of this system is strongly urged by the curator at Exeter. Mr. Moore, of Liverpool, was probably the first to adopt the pictorial family group arrangement.

15. *Condition of Specimens.*—The most perishable contents of a museum are its specimens of natural history. Unless they have been well cured and are carefully excluded from damp, from infection, and from too much direct sunlight, they will rapidly deteriorate. About 100 museums report their natural history collections as in good condition; in about 25 they require more or less renewal. The cleaning of stuffed specimens which have become dirty is a process requiring care and knowledge. Many are spoilt by well-meant but ignorant attempts.

16 and 17. *Arrangement.*—In all good natural history collections there will be, in addition to the stuffed vertebrates, a number of skeletons and of specimens preserved in bottles. About thirty museums report that the skeletons and bottles are grouped with the stuffed specimens, in about forty-five they are kept separately. In some no regular system is adopted, in others the skeletons and bottles are too few to be considered.

The usual system of arranging fossils is to group them stratigraphically in the first instance, and zoologically within the stratigraphical groups. About a dozen museums, not of the lowest class, report that their fossils are not arranged at all.

A phylogenetic arrangement of organic forms is advocated by some authorities. Professor Herdman, of Liverpool, has elaborated a plan for such a collection, but it has not yet been carried out.

In furnishing a new museum it is wise to determine upon a scheme, to provide cases sufficient to carry this out, to place all specimens in their permanent places, and to fill up the blanks gradually.

18, 19. *Local Collections.*—About one-half of the provincial museums

have some distinct local collections; in the remainder no distinction is made. Only sixteen museums are reported to be entirely or chiefly devoted to local collections. At Hereford and at Dumfries no foreign specimen is admitted, but in most of these sixteen there are foreign types or small foreign collections.

That provincial museums should chiefly devote themselves to the thorough and complete working out of the productions of their own districts is now the opinion of the great majority of competent authorities, and the same view is urged by the curators of many of the leading museums, as Liverpool, Cambridge, Bristol, Brighton, Exeter, &c. In no single instance has this yet been accomplished. To do it in a satisfactory manner would task to the utmost the resources of any average first-class museum; but the interest, the novelty, and the immense scientific and social value of such work would much better repay the cost and labour than the fragmentary and often aimless collections which are now gathered from all quarters of the globe.

The leading character of such local collections as now exist depends partly on the locality and partly on the favourite pursuits of the curator or of the amateurs of the district. In some places the local geology is well worked up while the zoology is neglected, or the archæology and the shells may be looked after while there is no one to take much interest in the geology, the botany, or the birds and insects. This is the consequence of trusting to amateur collecting and of the want of a definite ideal to work up to.

To exhibit the local productions as completely as possible, showing very distinctly what groups are not represented in the district, and to supplement these collections by well-selected types of foreign species for comparison and for carrying the observer's mind beyond the narrow limits of his own country, carefully arranging these types so that comparison shall be easy—this seems to be the best which museums can do in this direction.

20. *Educational Collections.*—A number of museums report that their collections are arranged throughout with an educational purpose. The museums attached to some of the large provincial colleges are, however, designed for the special illustration of certain text-books or certain courses of lectures, and are therefore more definitely educational. Some of the larger museums have prepared sets of specimens illustrating different branches of science for lending to the surrounding schools, and at Liverpool a system of small circulating museums has been established with excellent results. At Leicester there is a useful osteological collection, showing by colour on a series of skulls, &c., the various forms assumed by the same bone in different animals. Truro is one of the few of the smaller museums which possess a laboratory and theatre with chemical and physical apparatus.

21. *Industrial and Technical Collections.*—Only about thirty museums appear to have given any attention to this department. Some of these have provided collections illustrating the manufactures of the districts, showing materials, processes, and results. Others have collected foreign examples of the local manufactures, or choice designs of art-work for the assistance of local workmen. At the Edinburgh Science and Art Museum Industrial Art is made a leading feature. At Dublin a new building is being erected especially for such collections. At the Queen's Park Museum, Manchester, there is a general collection of substances used as

food. At Beaumont Park Museum, Huddersfield, there is a collection of injurious insects. The Ancoats Hall Museum at Manchester, which is especially devoted to the culture of the sense of beauty in nature and art, has some interesting collections of furniture and of art processes.

22. *Classes.*—Except at the museums connected with the universities and large schools there appears to be very little class work carried on in these institutions. At two or three places regular courses of lectures by certificated science teachers are held either in the museum or in rooms adjoining. Several museums provide a series of popular scientific lectures during the winter evenings, and at several others short explanatory addresses are delivered at stated times in the museum rooms by the curator or the honorary curators. A few of the local societies hold classes in their own museums. Beyond these there are no actual teaching arrangements, though these institutions seem to offer so many advantages for that purpose.

23. *Local Students.*—About fifty museums report that they are used for frequent reference and study by local naturalists, archæologists, and medical and art students. Nearly an equal number state that there is unfortunately very little use made of them by such persons.

24. *Facilities for Study.*—Many museums report that they would welcome students and give them every assistance, but that none apply. About twenty museums have private rooms which they would gladly place at the disposal of students, and about thirty can provide tables though not rooms. In a few instances local students avail themselves of these facilities to a considerable extent. Microscopes for students are provided in about twenty-five museums. In about fifty museums the handling of specimens is distinctly allowed, generally under supervision, while in twenty it is as distinctly forbidden.

25. *Other Uses of Museum Rooms.*—Museums belonging to local societies are frequently kept in rooms which are used for the society's meetings. In a few public museums evening lectures and concerts are given, but in the great majority of cases the rooms are not used for any other than their legitimate purpose.

26. *Aquaria and Vivaria.*—These interesting and instructive contrivances appear to be generally neglected. Not more than about a dozen museums have anything of the kind. The Liverpool Free Museum seems to be the only one which makes an important department of them. Here, however, in the basement, between forty and fifty tanks and cases ot various sizes have been kept up for a long period. 'One large salt-water tank has been in continuous use for over twenty-five years. Fish have been kept for ten years in the medium-sized tanks, and in a smaller glass vessel a blind crayfish from Kentucky has lately died, after fourteen years' confinement therein.' The value of such arrangements for studying the life-histories of many organisms must be very great. It is possible to keep even marine aquaria in inland towns. Some years ago a salt-water tank with a fine collection of sea-anemones, &c., was maintained for several years at Leicester.

27. *Handbooks.*—It is perhaps undesirable to publish 'catalogues' of growing museums, as they are so soon out of date; but catalogues of all completed and of all special collections should undoubtedly be published. This is generally done by the best museums, and sometimes in a very sumptuous and elaborate style. The handsome illustrated quarto volumes forming the 'Descriptive Catalogues' of the Woodwardian Museum at

Cambridge were prepared by such authorities as Sedgwick, McCoy, and Salter. The Blackgate Museum, Newcastle-on-Tyne, issues a catalogue of inscribed and sculptured stones, illustrated by nearly 200 admirable woodcuts. The catalogue of the Duke of Newcastle's Museum at Alnwick Castle is richly illustrated. The Saffron Walden Museum has also a rather costly illustrated catalogue. The Edinburgh National Museum of Antiquities has issued an illustrated catalogue at the price of sixpence, of which nearly 20,000 copies have been sold.

The Liverpool Museum has several illustrated catalogues of the Mayer Collection of Art Treasures, and has issued a series of 'Museum Reports' upon some special collections of mollusca and lepidoptera, illustrated by coloured plates. Besides the above, only about twenty museums appear to possess permanent catalogues, not illustrated, about an equal number publish handbooks and guides, which are sold at various prices from one penny to sixpence, and a somewhat larger number issue Annual Reports, in which the progress of the museum and the donations of the year are registered. Some of the handbooks and guides are exceedingly well done, giving a vast amount of information in a terse and popular style. Those issued by the Liverpool Museum; the Marlborough College; the York Philosophical Society; the Albert Institute, Windsor; the Free Museum, Nottingham; the Sheffield Public Museum; and the Agricultural College, Cirencester, are particularly good. The Liverpool Museum has published a 'Museum Memorandum Book,' prepared by the Rev. H. H. Higgins, 'containing plans showing the main features in the Natural History Department of the Liverpool Free Public Museum, with ruled spaces for memoranda invited to be made on the spot, price one penny; pencils ready pointed, one halfpenny; millboard tablets for writing on, one halfpenny.' This is a novel and very interesting experiment, and shows that the authorities of this museum are devoting thought and labour to the task of making their museum as widely educational as possible.

28. *Duplicates.*—The large number of duplicates which accumulate in many museums and are stored away for years in drawers or boxes might be of considerable value if they were distributed. Curators often feel this, but the distribution is difficult to accomplish. Many of the duplicates were gifts, and there is an unreasonable idea that gifts must not be given away elsewhere; many, being little cared for, lose their labels and become valueless. Moreover, there is much difficulty in ascertaining where particular duplicates are wanted and what can be got in exchange. About fifty museums report that they have large collections of duplicates, and about twenty-five have a small number. At Birmingham, Brighton, Nottingham, Salford, and Cardiff a large number of duplicates are distributed to schools or other museums as fast as they come in. The Dublin Science and Art Museum is organising its duplicate department for the purpose of periodical distributions to other Irish museums.

A well-understood system of exchange is much wanted. Suggestions have been made that museum inspectors should be appointed, charged, among other duties, with that of arranging exchanges. Others have suggested the formation of a society of curators, meeting periodically.

29. *Help from Local Societies.*—Many of the museums now belonging to the public and supported by the rates were originated by local societies. In some of these cases the societies still render valuable assistance,

but there is sometimes a disposition to eliminate this element as trenching on the domain of the regular officers; and sometimes the societies, feeling that they are no longer responsible for the maintenance of the museum, lose interest in it. Only about a dozen of the rate-supported museums report that they are receiving any assistance from local societies.

30. *Donations.*—Nearly all museums, except the smallest and the most neglected, receive donations from time to time, though many report that these are 'mostly worthless.' The donations come from all classes of the community. Many are sent from old inhabitants now living abroad; sea-captains and sailors carry home many objects which they present to the museums of various ports; artisan naturalists bring in the fossils or the eggs or the insects which they find in the neighbourhood. Hitherto this desultory method of accumulating a promiscuous mass of objects has been almost the only resource of a large number of museums. It has its advantages, and should by no means be ignored or discouraged; but if museums in the future are to do the scientific work of which they are capable and which waits to be done, this must only be relied on as supplemental to a much more systematic method of collection.

31. *Labels.*—A museum without labels is like an index torn out of a book; it may be amusing, but it teaches very little. It is true that, when vertebrates are set up pictorially, labels injure the picturesque effect, but picturesqueness is not the chief object of a museum. The Leicester Museum, having set up all its vertebrates in pictorial style, has made an attempt to do without labels, and the result is instructive. Instead of labels or numbers there is a small coloured sketch of each group with small numbers near each figure. The figure of the specimen of which the name is required has to be found on this sketch, the number noted and carried to a separate printed card in rather small type; here the number has to be found, and the name and particulars are then obtained. Afterwards the specimen has to be found again in the stuffed group, and if any of the information is forgotten the process must be repeated. This is much too complicated and wastes too much time. The cases are a little more showy than they would be if labels were dotted all over them, but the sacrifice is far too great.

A few old museums still preserve the practice of numbering their specimens and registering them in a manuscript catalogue which is open to visitors. Such a register should always be kept as a check, but should not be allowed to take the place of labels. Effective labelling is an art to be studied; it is like style in literature. A good writer conveys his meaning clearly, tersely, artistically. The reader grasps the thought with the least possible effort and with a pleasing sense of elegance and harmony. A good labeller produces the same effect. It is to be attained by a combination of well-chosen words, expressing well-arranged ideas in carefully selected type on paper of appropriate colours. In the smaller museums the labels are generally written by hand, and in a good many larger ones this system is still continued; many have printed headings and fill up the details with the pen; the best museums have nearly everything fully printed. Some have set up small printing-presses on the premises, with which the curator prints his own labels, but in most cases this is not a success—the work is done too roughly.

In some museums the English name is always placed first in the boldest type; in others the scientific name takes the lead in genera, the English in species. Some museums possessing classical collections

indicate on the labels those specimens which have been figured. The Elgin Museum indicates geographical distribution by a system of tinted labels. At the Queen's College Museum, Cork, the minerals are mounted on thick wooden blocks, painted white and with the front upper edge bevelled to receive the label.

The best museums are not now content with labelling the specimens, but place also with each group printed tablets describing in popular language the generic or family characters, so that they become museums and libraries combined, and a student may get at once almost all the information he needs.

The Nottingham and Manchester Museums have introduced an effective style of large-type labelling, the letters being punched out of white cardboard and glued upon a black ground.

It is important to consider the amount of description or information which can be got upon a label without overloading it. The more the better, so that the type is clear and not too crowded, and the label not too large.

32. *Libraries.*—Nearly half of the rate-supported museums are attached to free libraries and use the books there provided. A good many other museums are attached to colleges, schools, and institutions which possess libraries. But where there is no such accommodation, a library of reference on the spot is absolutely essential to every active museum. About sixty museums report that they possess such libraries, varying in number of volumes from 10 to 10,000; but only a few of them appear to be adding annually to their contents, and many of these volumes are bound Reports of various societies, which though valuable are not the most available sources of information for a working curator. A good museum should have at least 500 volumes of the best standard works of reference on all branches of zoology, geology, botany, and archæology.

33. *Visitors.*—There are few museums in the country of any value from which visitors are entirely excluded, but if they can only be seen by special application their value to the public is greatly restricted.

Some of the smallest museums are not visited by more than two or three persons in the course of a week. About twenty-five museums admit that their visitors do not exceed thirty per week. About fifty record them at 500 and upwards. Liverpool, Edinburgh, and Salford give their weekly average as 7,000. Where all visitors pay for admission, even if it be only one penny, the numbers never exceed 500 weekly, and rarely reach half that number, unless there be public gardens or other attractions included. Art museums with art galleries are largely attended, but the pictures are the great attraction. The Birmingham Art Gallery has reached an average of over 20,000 for some weeks in succession. Some museums are open free on certain days in the week and make a charge on the other days. The charge rarely exceeds sixpence each for admission to a museum only. About a dozen museums, several of them large ones, state that no record of visitors is kept, and that they are unable to estimate the numbers. Various methods are used for recording or estimating the weekly attendance. The most efficient is the automatically recording turnstile, which costs however about 50*l.*, and does not appear to be in use at more than twenty museums throughout the country. The larger museums which are without turnstiles employ some person either at irregular intervals, or

for a week together at several times of the year, to count the numbers who enter, and from this imperfect record an estimate for the year is made. Smaller museums have a visitors' book, in which each must sign his name on entering. Where an admission fee is charged the money taken indicates the number. In the few cases in which museums are opened on Sunday afternoons they appear to be largely attended.

34. *Situation.*—The great bulk of the public museums are centrally situated in the midst of the populations for whose benefit they are intended. The few which are not so are either included in public parks and botanic gardens or are attached to institutions erected in the suburbs. It is not easy, therefore, to estimate the effect of this difference, but there seems to be some evidence that while a suburban situation deters visitors during the working days, it tends to attract them on holidays. The curator at Cardiff reports that his museum 'is too central, in the heart of the smoke and dust,' and that a new building is in progress. Dusty and noisy situations are undoubtedly objectionable.

35. *Busiest Time.*—In museums generally the busiest time is the afternoon, and next to that the evening, while only about half-a-dozen record their busiest time as the morning, several of these being at fashionable watering-places. A large number are crowded on public holidays, while a few state that they are not affected by holidays at all, and about half-a-dozen close their doors on those days. Those which are open on Sunday afternoons give this as one of their busiest times.

36. *Remarks.*—Suggestive remarks were made by many curators under this head. Some of them have been already referred to. Many urge the importance of provincial museums giving their chief attention to local collections. Several speak of the great want of workrooms; of the necessity of fully descriptive labels, and explanations of words and names such as 'majolica,' 'vertebrates,' &c.; of the desirability of collections of scientific apparatus, of a good supply of seats in the rooms, and of the importance of getting some alteration in the law of treasure-trove. One thinks that Sunday opening is not required; another wishes he could persuade his committee to adopt it.

Several point out the importance of having museums controlled by scientific curators, not by town councils or amateurs, and urge that at least the committees of town councils should associate with themselves some gentlemen of scientific reputation, which is in fact done by a considerable number of such committees. Several others feel the need of some organisation among curators, either nationally or in districts, for mutual help and co-operation.

The great question of funds is a perpetual source of complaint. Societies are nearly always short of money; and when a town adopts the Public Libraries and Museums Act it generally tries to get both institutions, and often an art gallery as well, out of the penny rate. The consequence is that, except in very large towns, all are crippled. In a town of 100,000 inhabitants the penny rate will raise on an average perhaps 1,500*l.* This would be sufficient to carry on only one of these institutions in a vigorous and successful manner. It is not nearly sufficient for two, and is useless when divided among three. Several towns have now obtained in private Acts the power to levy twopence for these purposes. There is a considerable feeling of disappointment that the trustees of the Great Exhibition Fund have refused any assistance to provincial museums, although much of that fund was derived from provincial sources.

The present Report includes only four of the six sectional headings under which we proposed to treat the subjects entrusted to us. Want of time and of data have made it impossible for us to consider with sufficient seriousness the questions of the ideal museum, and of the best practical methods for approaching it. Yet, as the answering of these questions forms the chief object of our inquiry, we ask to be reappointed for another year, that we may have the opportunity of collecting information by two other important methods which are at present practically untried, viz., the personal visitation of a number of museums in different parts of the country, and inquiries respecting those which exist in Europe and America; and that thus, with the whole statistics before us, we may endeavour to formulate such a scheme for the working of provincial museums as would bring out their fullest capacity for educational purposes.

First Report of the Committee, consisting of Professor HILLHOUSE, Mr. E. W. BADGER, *and* Mr. A. W. WILLS, *for the purpose of collecting information as to the Disappearance of Native Plants from their Local Habitats. By* Professor HILLHOUSE, *Secretary.*

THE question of the extirpation of native plants from many localities was brought before the members of the Birmingham Natural History and Microscopical Society in 1884 by Mr. A. W. Wills, and an article on the subject communicated by him to the 'Midland Naturalist' for August of that year.[1] At the meeting of the Midland Union of Natural History Societies at Birmingham in June 1885, Mr. Wills, in conjunction with the other two members forming this present Committee, brought the matter up; in the first instance before the Council of the Union, and afterwards, with their cordial approval, before the Conference of Delegates from the societies constituting the Union. An 'appeal,' passed by this Conference, and circulated amongst scientific societies, was, by request of the then secretaries, laid by the writer of this Report before the Committee of Section D of the British Association at its meeting at Aberdeen, 1885, and by it referred, with cordial approval, to the Conference of Delegates of Corresponding Societies. (See the proceedings of this Conference in the Report for the Birmingham meeting, 1886.)

Between the dates of the Aberdeen and Birmingham meetings a considerable mass of information bearing upon this question was collected from different sources, and letters of approval were received from various quarters, including one expressing the full sympathy of the President and Council of the Royal Society with the efforts of the Midland Union for the preservation of the native flora of Great Britain; and finally, at the Birmingham meeting, 1886, these initial labours were crowned with their highest possible reward in the constitution of the present Committee.

For the purpose of carrying out its objects the Committee have addressed to local Natural History Societies and Field Clubs, and to local botanists, a circular asking the following questions:—

1. Have any plants, of comparative rarity or otherwise, disappeared from your local flora in recent years? If so, kindly enumerate them,

[1] Vol. vii. p. 209.

specifying the original habitat of each, and giving the cause, or probable cause, of extirpation so far as known to you.

2. As above, but referring to partial instead of complete disappearance.

3. If you know personally of any cases of extirpation, partial or complete, in localities other than your own, please give them.

For convenience in collating, it is requested that answers under these three heads may be given separately in schedule form as follows, and that the plants may be arranged with the names, numbers, and sequence of the latest edition of the London Catalogue.

No. in London Catalogue	Name of Plant	Habitat	Cause of Disappearance (or of Diminution)

4. To what extent do you think that the partial or complete disappearance of plants from any localities known to you was, or may be made in the future, subject to public or private control?

The Committee do not consider it any part of their present duty to express opinions or make suggestions. Not until the fullest possible information upon the disappearance of plants from their local habitats, and the causes thereof, has been obtained upon personal and sufficient authority, can the question of remedy be taken into consideration, if, indeed, investigation should show that remedial action is necessary or possible; and the Committee are not without hope that the awakening of local societies to the importance of the subject may lead to the gradual formation of such a healthy tone of public opinion as will render further action unnecessary. Nevertheless, it is considered desirable to ask the above question No. 4, in order to elicit the views of diverse and widely distributed correspondents.

In order to avoid undue demands upon time and space, and to minimise the clerical labour involved in such an extended investigation as this, the Committee propose to spread it over a short series of years, confining its attention in each year to some well-defined area. At present they are limiting their inquiries to Scotland, and propose to collate the results for the meeting of the Association in 1888.

Report of the Committee, consisting of Professor McKendrick, Professor Cleland, *and* Dr. McGregor-Robertson (*Secretary*), *appointed for the purpose of investigating the Mechanism of the Secretion of Urine.*

Your Committee have to report that they have conducted a series of experiments having specially in view the desire to discover, if possible, any new evidence regarding (1) the mechanism of the separation of the watery constituents of the urine, (2) the mechanism of the separation of the nitrogenous constituents, and (3) any cause of the appearance of albumen.

A few experiments previously made by one of us seemed to indicate that the influence of atropine on the kidney would aid in such an inquiry,

and it was, indeed, because of such an indication that the investigation was undertaken. The animals hitherto experimented on were cats and rabbits. The method employed was as follows:—

The animal was confined in a large cage, supplied with a double bottom of zinc. The false bottom was perforated, allowing the passage of urine, but retaining the fæces. At one end of the real bottom a tube conducted into a receiver, where the urine was collected. The urine was collected once in twenty-four hours, and was usually quite clear and free from foreign admixture. In order to simplify the experiment and avoid as far as possible variations due to different quantities of food, the animal was fed on a stated quantity of porridge, made of a weighed quantity of meal, and there was added a measured quantity of milk. The animal was in all cases kept for a week or more on the regulation diet before the observations began, until the urine, in regard to total quantity and to constitution, became steady. Variations were thus easily observed, and the risk of error in assigning the cause much diminished.

After the urine had become steady, and a record of the quantity and amount of nitrogen present had been taken for a number of days, atropine was injected hypodermically and its effects on the urine observed. The total nitrogen was estimated by the method of Knop and Hüfner, a large number of estimations of urea by the method of Liebig having led to its abandonment.

Some of the results are given in tabular form as obtained from the cat. They are a fair sample of the results obtained in every one of a large number of observations on the cat.

The first table gives the results of two consecutive experiments on the same cat.

TABLE I.—*Cat.*

Total Urine in 24 hours in c.cs.	Total N. in grms.	Remarks
190	1·786	
175	1·802	
Half a grain of atropine injected.		
179	1·950	
148	2·490	Bare trace of albumen.
175	1·837	
200	1·800	
170	1·700	
One grain of atropine injected.		
132	1·973	
98	2·352	None of the food eaten.
50	2·920	Only 190 grms. of a total of 270 grs. food supplied eaten.
205	2·665	Trace of albumen. 230 grms. of total food eaten.
170	2·210	Faint trace of albumen. All food eaten.

The table shows that after the injection of atropine the total quantity of urine falls and the total N. rises: this is more marked with the larger dose of atropine. The increased elimination of N. occurs in spite of a lessened consumption of food. In two or three days after the injection

a great increase occurs in the total quantity of urine, while at the same time the elimination of N. is diminishing. In some of the experiments, though not shown in this table, the total N. fell below the average, while the total quantity of urine rose much above the average.

As tested by the specific gravity, the other solid constituents of the urine did not seem to vary.

Where no remark regarding food is made, it must be understood to have been all consumed.

The following tables give the results of a single experiment with two different cats:—

TABLE II.—*Cat.*

Total Urine in 24 hours in c.cs.	Total N. in grms.	Remarks
176	2·200	Each day a small quantity of food left; about the same quantity each day.
190	2·945	
224	2·531	
One grain of atropine injected.		
185	5·457	Of a total of 460 grms. food supplied only 190 grms. eaten.
140	4·270	230 grms. food eaten.
246	2·509	410 grms. food eaten.
206	2·884	Food all eaten.
235	2·232	Trace of albumen. Food all eaten.
306	2·754	Trace of albumen disappeared.

TABLE III.—*Cat.*

Total Urine in 24 hours in c.cs.	Total N. in grms.	Remarks
250	1·850	
232	1·856	
Injected one grain atropine.		
192	2·899	Only 195 grms. food (of total 370 grms.) eaten.
186	2·641	130 grms. food eaten.
212	1·759	230 grms. food eaten.
290	2·436	Trace of albumen. Food increased to 400 grms.; all eaten.

These tables show results similar to table I. After injection the nitrogen rises in spite of the greatly diminished consumption of food, while the total urine falls. Two or three days later the total urine rises, while the N. falls. At the same time the ability of the animal to take the usual quantity of food is returning. The changes that have been indicated are markedly shown in table II.

A series of experiments was conducted on rabbits. While supplying no results contradicting any of those mentioned, none confirming them to a satisfactory extent was obtained. This seemed to be due to the marked

insusceptibility of rabbits to the influence of atropine. Under the influence of one grain of atropine, and even of half a grain, cats are markedly excited, are unable to take food, and exhibit evidences of serious disturbance. Rabbits show no such symptoms. Even a dose of 4 grains of atropine seemed to have little disturbing effect, but with that dose results as regards the urine indicating an approach to those of the cat were obtained.

As regards the appearance of albumen, in the majority of instances traces of albumen were obtained some time after the injection of atropine; in a few, quite distinct evidence of its presence in very small amount The evidence was usually most distinct at the time when the total urine was rising and the total N. falling. But regarding albumen, no results were obtained definite enough to allow of any conclusions being drawn as to its relation to the separation of nitrogen.

In cats on whom several experiments had been made there seemed to be some degree of tolerance of the drug; but though a few experiments were tried directly in relation to albumen they yielded nothing definite. The Committee next considered whether a method could be adopted which would admit of microscopic examination of kidneys of animals submitted to the influence of atropine.

For this purpose a number of rabbits were injected with a solution of indigo-carmine, after the method of Heidenhain. The rabbits were first of all injected with atropine in varying doses and at varying intervals; after its administration the indigo-carmine was injected. It was thought that if any marked influence were exerted on the renal epithelium, it might be indicated by variations in the extent to which the colouring matter was picked up by the cells. Though the injections were satisfactorily enough accomplished, the experiments yielded no information beyond what might have been expected from Heidenhain's description of what normally occurs. It may be, however, that the insusceptibility of rabbits to the influence of atropine renders them unsuitable subjects for such an experiment. The Committee think it probable that this method might yield some results with cats or other animals, and a further set of trials in this direction may yet be conducted by one of the members.

Your Committee think that what evidence has been obtained strongly supports the view that the mechanism for the separation of the watery constituents of the urine is different from that for the separation of the specific constituents. The effects of atropine which the experiments demonstrate could be explained by a stimulating action on the renal epithelium, followed by a paralysis or state of exhaustion. This, at least, would account for the great increase in the elimination of N., followed by a decrease. It would also account for the diminution of water, followed by an increase, if the cells were supposed to possess the function of absorbing water to any extent. The meagre results relating to albumen do not justify the offering of any suggestion regarding its appearance.

Your Committee think that a continuation of the experiments on the lines of some of the methods indicated, as well as on others, might elicit further facts of value. One of their number hopes to be able himself to pursue the subject further, and if he obtains any results to communicate them to some future meeting of this Association. In view of this the Committee respectfully suggest they might now be discharged.

Report of the Committee, consisting of Mr. E. BIDWELL, Professor BOYD DAWKINS, Professor BRIDGE, Mr. A. H. COCKS, Mr. E. DE HAMEL, Mr. J. E. HARTING, Professor MILNES MARSHALL, Dr. MUIRHEAD, Dr. SCLATER, Canon TRISTRAM, *and* Mr. W. R. HUGHES (*Secretary*), *appointed for the purpose of preparing a Report on the Herds of Wild Cattle in Chartley Park, and other Parks in Great Britain.*

ANY inquiry into the origin of the Wild White Cattle would be beyond the scope of the present Report, and this question, however interesting in itself, must be dismissed in a very few words.

The Urus (*Bos primigenius*) was probably the only indigenous wild ox,[1] not only in this country, but throughout the Palæarctic region, and the source of all our domestic breeds, as well as of the White Park Cattle; and we may fairly trace these park herds back to the *Bubali* or *Tauri sylvestres*, which are mentioned[2] as occurring down to mediæval times; but whether these animals were genuine Uri, or *feral* cattle, admits of some doubt.

The original Urus was a huge beast, while the park cattle, as we know them, are smaller than many domestic breeds; but deterioration in size would be a natural result of their way of life and long-continued in-breeding.

The prevailing white colour of the park herds, with a tendency to throw black calves, which still exists in most of the herds, and which is especially the case when any admixture of blood takes place, is probably the result of the same cause, and not the original coloration of the Urus. White cattle had a special value, according to the Welsh laws of Howell Dha, and as is also proved by the present sent by Maud de Breos to appease King John.

This report does not include extinct herds, but as one herd—that in Lyme Park—has only very recently ceased to exist, and as this is the first account of the wild cattle published since that catastrophe, it has been thought well to include a short notice of that ancient stock.

The following list includes all the herds now remaining in the British Isles, arranged according to the probable order in time of their arrival at their present abode. In the detailed account of the different herds further on, they are arranged to some extent geographically, from north to south.

Chartley Park, near Uttoxeter, Staffordshire (the Earl Ferrers), appears to have been enclosed by the middle of the thirteenth century.[3]

Chillingham Park, near Belford, Northumberland (the Earl of Tankerville), seems to have been enclosed before the latter part of the same century, and probably as early as (or even before) 1220; and should therefore, perhaps, have been placed first.

Lyme Park, near Disley, Cheshire (W. J. Legh, Esq.), at the latter part of the fourteenth century.

Cadzow Park, Hamilton, Lanarkshire (the Duke of Hamilton, K.T.).

[1] *I.E.*, of the genus *Bos*; there was in addition the bison.

[2] By Matthew Paris, Fitz-Stephen, and others.

[3] For these dates *vide* authorities quoted by Harting, *Extinct British Animals.*

Date of enclosure unknown, but the present park occupies a portion of the old Caledonian Forest, in which Robert Bruce is traditionally stated to have hunted the wild bull in 1320, and where in 1500, James IV. of Scotland took part in the same wild sport.

The above are probably the only herds remaining on the ground in which they were originally enclosed.

Somerford Park, near Congleton, Cheshire (Sir Charles W. Shakerley, Bart., C.B.) The cattle cannot be traced here more than about 200 years, though it is possible they have been there since the original enclosure of the park; it is perhaps more likely that they were brought in the seventeenth century from Middleton Park, Lancashire, which herd in turn is supposed to have come from Whalley Abbey.

The Middleton Herd is now represented by offshoots (to some extent cross-bred, however, and now, like the Somerford herd, domesticated) at Blickling, near Aylsham, Norfolk (the Marchioness of Lothian), and at Woodbastwick Hall, near Norwich (A. Cator, Esq.). The cattle were removed from Middleton about 1765 to Gunton Park, Norwich (Lord Suffield), where they became extinct in 1853; but some had meanwhile—viz., between 1793 and 1810 [1]—been introduced to Blickling, and others in 1840 were sold to Mr. Cator of Woodbastwick.

The herd at Vaynol, near Carnarvon (G. W. Duff-Assheton-Smith, Esq.), was started in 1872 from stock purchased from Sir John Powlett Orde, of Kilmory House, Argyllshire. This stock (now somewhat crossed) was originally at Blair Athol, Perthshire. In 1834 the herd was sold to the Marquis of Breadalbane, Taymouth, and to the Duke of Buccleuch, Dalkeith. When the latter herd was broken up, the late Sir John Orde purchased the only survivor and transported it to Argyllshire. In 1886 the entire remainder of the Kilmory herd was transferred to Vaynol, and added to the cattle already there.

At Hamilton, Chartley, and Somerford persons who have known the herds for a number of years have expressed the opinion that the cattle have somewhat deteriorated in size within their recollection; but there is nothing to prove this, and it must be recollected that by degrees things appear smaller than the recollection of the first impression received as children.

At Chillingham, Chartley, and Hamilton, the wild cattle's heads seem slightly larger in proportion to their bodies than in ordinary cattle, the feet larger and broader, and the legs stouter. May not these be taken as indications of a certain amount of deterioration in their size?

At Chillingham the cattle have a 'fine-drawn' almost 'washed-out' appearance, which may be considered the result of close breeding, and the fact of more male than female calves being born is probably the effect of the same cause.

It is interesting that in the semi- or wholly-domesticated herds at Vaynol, Somerford, and Woodbastwick the calves are extremely shy when first born, and only become accustomed to human beings by degrees.

If it is not beyond our province to make a suggestion, it would be extremely interesting if the noble owners of the three ancient herds would co-operate with some other owner of a large park—if haply such could be found—willing to undertake the following experiment:—Namely, that all calves which would ordinarily be converted into veal or steers should

[1] Storer, *Wild White Cattle*, p. 307.

instead be sent to build up a new herd, which, combining the blood of the only remaining ancient herds, and with no artificial selection exercised, might be expected to revert more nearly to the aboriginal wild type than could be achieved in any other manner.

Hamilton (*Cadzow*).—On August 22 last the herd was made up somewhat as under :—Bulls : 2, six years old ; 1, five years old ; 2, three years old ; 6, two years old ; five calves ; total, 16 bulls. Females : 25 cows, four years old and upwards ; 10 heifers, two years old ; 9 yearlings and calves ; total, 44 females. Total, 60 head (against 54 at the beginning of the year).

The coloration and markings are tolerably uniform, though ten years ago, at any rate, there was a variety in the amount of black on the outside of the ears, and in a slight degree in the amount on the muzzle. Any that are defective in their points are slaughtered or made into steers ; there are none of the latter at the present moment in the park, but two were shot last October, and some of the young bulls will be operated on in the fall.

There is a good deal of black on the forelegs in this herd, the hoofs are black, also tips of horns, roof of mouth, and circle round eyes ; black calves are frequently born, ten years ago the average was about three annually.

Three years ago a bull, which was considered as a Highland bull, arrived from Kilmory ; it was marked precisely like the Hamilton cattle, but one of its progeny was white all over, and another was black, so the bull and all its stock were killed.

The new blood was introduced in consequence of an idea prevailing that the breed was deteriorating from too close breeding.

Last year (1886) a bull was procured from Chillingham, and perhaps greater interest attaches to the result of this admixture of blood than any other event in connection with the White Herds of recent years. The first two calves were born in March last, and three others somewhat later. Four of these were males, and only one a female. Three of the bull calves took after their sire in having brown ears, and have been destroyed.

The remaining bull calf is described as beautifully marked, with black points after the Hamilton pattern.

The heifer calf has her ears slightly tipped with a few brown hairs, but the keeper thinks she may throw well-marked calves by a Cadzow bull.

There is no certain evidence of new blood having previously been introduced into this herd, however unlikely it is (as shown by Storer) that a small number of cattle could have been continually bred only *inter se* for centuries, and the herd still exist. But Sir John Orde [1] was told that one, if not two, Highland bulls bred in the herd some years ago.

With regard to what has been recorded as to this herd being formerly polled, the following appears to be fresh evidence :—Joseph Dunbar, a labourer who has been in the ducal service for about fifty years, says that forty-five years ago (say, 1842) the cattle were all hornless, and the present duke's grandfather caused all showing the least appearance of being horned to be killed.

The calves are all born here in spring and early summer ; to ensure this the bulls are kept in a run apart from the cows during the greater part of the year. At the present time the Chillingham bull is in a third

[1] Storer, *Wild White Cattle*, p. 342.

enclosure with seven cows (in March the Chillingham bull was by himself, and the ten calves then in existence in a fourth enclosure).

When the grass is scanty, hay and turnips are given, and the cows in addition get a little cotton-seed cake.

The keeper (Scott), who has known them for upwards of twenty years, says they are much less wild and dangerous now than formerly, in consequence of being visited by so many people of late years.

Chillingham.—In October last the herd numbered 60 animals; this has been the average number during the last twenty-three years (Lord Tankerville wishes to raise the number to 70, which is sufficient for the extent of the park). During the above period 113 male calves and 105 females have been dropped, averaging over nine a year. The deaths have averaged about ten annually. The causes of death, besides the shooting of oxen and an occasional aged or sickly bull or cow, include old age, drowning, injuries received in fighting, rupture, cancer, fall, and other injuries; poverty and want of food; and, in calves, the failure of the dams' milk.

The cattle live on good terms with the red deer, but they will not tolerate fallow deer or sheep in the park, possibly because they eat the pasture too close, or more probably from the fact of the red deer being like themselves primæval denizens of the forest.

They will never touch turnips. During the last few winters ensilage has been given them along with the hay. For a long time none of them would touch the ensilage. They sniffed at it and turned away. Even when all the hay had been eaten the ensilage remained untouched. At length a young bull was seen to try the ensilage; he went back to the herd, and they returned to the ensilage with him. Since then the ensilage is always finished before the hay is attacked. It is not thought prudent to give very much ensilage, as it appears to stimulate the milk in the cows too much for a time, and it afterwards fails.

One difficulty in increasing the herd is, that the cows continue to suckle their calf even after a second calf is born, and the latter is consequently left to starve. The calves dropped in winter suffer from want of milk.

The herd is subject to sudden panics, owing to strangers frightening them purposely to see them run, and several calves have been trodden to death in these stampedes.

Drowning in the marshes has been a frequent cause of death in wet winters and during thaws.

It is denied that any calves are dropped coloured otherwise than the correct white, with black extending very slightly beyond the naked part of the nose, and red ears, though in Bewick's time (towards the end of last century) there were some with black ears, and from the steward's book in 1692 there were not only several animals with black ears, but some were apparently entirely black and one brown.[1]

It is believed that Culley's celebrated shorthorns at the beginning of this century were bred by a cross secretly obtained with a Chillingham wild bull.[2]

[1] Storer, *Wild White Cattle*, p. 154; and Harting, *Extinct British Animals*, p. 234. Bewick, *Quadrupeds*, 8th ed. 1824, in a foot-note, p. 39: 'About twenty years since there were a few at Chillingham with BLACK EARS, but the present park-keeper destroyed them, since which period there has not been one with black ears.'

[2] Bewick, *op. cit.* p. 41 (foot-note): 'Tame cows, in season, are frequently turned out amongst the wild cattle at Chillingham,' &c.

During the last ten years Lord Tankerville has been trying the experiment of strengthening the domestic breed by crossing wild cattle and shorthorns. He commenced with a wild bull and two shorthorn cows. They produced a heifer and bull calf respectively, on June 10 and 17, 1877. Both the calves had red noses, though the male's was smutted with black; while the heifer (her dam's first calf) was the more correctly marked about the ears. The bull calf, being the first male of this new race, was named 'Adam.'

In April 1878 Adam's dam, a shorthorn cow, produced a bull calf by Adam. This bull when $3\frac{1}{2}$ years old measured 56 inches at the shoulder. In the following year Adam became the father of two more bull calves out of shorthorn cows.

In 1877 a wild yearling heifer was shut off from the herd, and the following year a second one, in continuation of this experiment. The elder one dropped a calf by a shorthorn bull in 1880, but it died; its fertility was afterwards at least temporarily impaired by a remarkable contingency, but in October 1881 both were supposed to be in calf to a shorthorn bull. None of these were to be added to the wild herd, nor were the wild cows to be ever readmitted.

Lyme.—Mr. W. J. Legh, writing on June 3 last, states that this 'herd ceased to exist about four years ago.'

It will be of interest, therefore, to mention what state it was in ten years ago, since which time we have no particulars of it.

The herd being on the decline as long ago as the year 1859, Mr. Legh purchased in October of that year the last surviving cow and calf from the Gisburne herd, and added them to his at Lyme.[1] The latest account published of this herd appeared in the 'Zoologist' for August 1878, and refers to a visit paid in June 1877. Correcting one or two obvious errors by comparing this account with Mr. Storer's, taken in August 1875, the following list includes the animals that were nearly, or quite, the last representatives of this ancient and interesting herd:—

One old bull, said in 1877 to be dying of old age, and to be eleven or twelve years old, though referred to by Mr. Storer in 1875 as three years old; one bull, brought from Chartley as a yearling, in 1877 was probably rising or upwards of seven years; one cow, aged about ten; one cow, out of the above cow, by the old bull, died previous to August 1875; one bull, out of the last-named cow, probably by the Chartley bull, sent to Chartley; one cow, *black*, out of the old cow first mentioned, by the Chartley bull, was in 1877 rising or turned five probably; one heifer, about two years old, by the old bull, out of the old cow, both first mentioned; one heifer, about eighteen months old, out of the black cow, by the old bull; one heifer calf, by the Chartley bull, out of a domestic cow; one heifer calf, from Vaynol.

Somerford.—In July last the herd consisted of thirty animals, made up as follows:—3 bulls—viz., one born about April 1885, one born about March 1886, one born about June 21 last; 18 cows of all ages, the youngest being about two years old; 5 heifers—viz., one about two years old, one born about February 1886, one born about May 1886, one born about June 1886, one born about September 1886; 4 heifer calves—viz., one born January, two born about end of April or beginning of May, one born July 21; total, 30.

No steers are reared; all surplus bull calves are fed for veal.

[1] Storer, *Wild White Cattle*, p. 290.

Three calves born this year have died—viz., one male from quinsy, two females born prematurely.

Two heifers were due to calve in September and four cows in October.

This will make a total of fourteen births during the year, from which we may infer that this herd is in no danger of extinction from shy breeding.

These cattle weigh up to fifteen scores to the quarter when fed for beef. They are thoroughly domesticated, and allow one to move freely among them, and the second bull permitted two visitors and Mr. Hill (the agent) to handle him simultaneously. The cows are all regularly milked. The butter made from them is pronounced the best in the county, and they are as a rule excellent milkers. The highest record (*fide* Mr. J. Hill) is thirty-three quarts per diem, but the drain on this cow's constitution proved fatal in about four months, notwithstanding everything possible being done in the way of feeding.

These cattle are polled, and no exception is known to have occurred. They are black pointed, but there is considerable range in the markings —far more than in any of the other herds. When Mr. Hill became agent, some nine years ago, he found the herd somewhat uncared for, and many of the cows so aged as to be past breeding, and he has therefore during that interval of time been keeping every good heifer calf, without weeding out too stringently on account of irregular markings.

About 1876 or 1877 a young bull was exchanged with the Marchioness of Lothian (Blickling). This cross succeeded fairly well; a peculiarity in this strain being that many are born with the ears square-tipped, as if the animal had been marked by cropping.

About the year 1879 a young bull was exchanged with A. Cator, Esq. (Woodbastwick). This bull was *brown* pointed, but threw calves with red ears and muzzles, which were the first so marked known to have occurred at Somerford.

Of the twenty-three cows and heifers, eleven have either very little black fleckings about the body or even none at all; while about six have a good deal of black in thickly grouped fleckings, spots, and small patches; two or three have probably fully one-third of the entire hide black. One cow, about ten years old, may be described as a blue-roan, black and white hairs being placed almost alternately over the greater portion of her body, which give her a *blue-grey* coloration. The fronts of her forelegs below the knees are black, and also the whole outside of her ears, instead of as usual from one-third to a half at the distal end. This cow was (according to Mr. Hill) giving twenty-four quarts of milk per day.

One cow is red pointed, and slightly flecked on the neck with the same colour. The black on the nose in the majority extends evenly round the whole muzzle, including the under jaw, but some have merely the naked part of the nose black, and in one or two even this is rusty coloured and not perfectly black. All, with the exception of the red-pointed cow, have a narrow rim of black round the eyes. The animals with the least black about them appear to have the finest bone and smallest heads. This may be following the old strain, while the others perhaps more nearly follow the cross-strains.

The red-pointed cow and one of the quite white ones have small knobs or excrescences on either side of the frontal bone, like budding horns, but they do not protrude through the skin.

One of the handsomest of the cows is almost entirely white, and is the daughter of a cow that died this year at the extraordinary age of twenty-three (at Chillingham they rarely reach ten) years. She was very dark, although of the old strain, and had withstood infection during the cattle plague epidemic.

The bulls (though both immature) are very strongly made, very broad across the thighs, short on the legs, and with remarkably broad, thick-set heads. Both are plentifully flecked with black, and in the younger of the two the fleckings extend to the lower part of his face, while the black on his muzzle is broader than in probably any other example of park cattle.

The old bull, aged eleven, was consigned to the butcher this spring, as he had become dangerous, having nearly killed the cattle-keeper.[1]

One of the cows and the younger bull have some black in their tail tassels, in all the rest it is quite white.

The bull calf and three of the heifer calves have very little black about them beyond their ears and muzzles, while the fourth is the blackest individual in this herd, having probably more black than white about it, in spots and patches with ill-defined boundaries.

The cows produce their first calf when from two to two and a half years old. The bulls run with the herd throughout the year, but, in order to in some degree regulate the birth of calves, individual cows are temporarily shut up.

The udders of the cows here, are as large as ordinary domestic cows', which is not the case in the herds which are not milked.

In winter all the cattle, especially the bulls, develop long hair on the poll and neck, which divides along the central line and covers them like a mane. The hairs decrease in length backwards to the withers, where they cease somewhat abruptly.

About 180 acres of the park are allotted to the cattle, consisting of excellent upland turf sloping down to the river Dane. It is said that the whole herd will sometimes gallop to a pond in their enclosure, and go in so deep that little but their heads remains visible.

In dry seasons, when the river Dane has become unusually low, instances have occurred of cattle of both sexes crossing the river both ways; but calves produced by the park cows are kept if correctly marked, &c., even when the sire was probably a common bull.

The cattle are housed at night during winter, and supplied with hay.

Chartley.—The herd in July last was made up as follows:—Bulls: 1, nine years old; 1, six; 1, four; 1, three; 1, yearling; 4 calves; in all, 9. Females: 6 cows, aged; 2 cows, four years old; 2, three; 2, two; 6 yearlings; 2 calves; in all, 20. Bullocks: 1, four years old; 1, three; 3, two; in all, 5. Total, 34.

This is the largest number recorded during recent years. An idea or tradition prevailed that the number could not be raised beyond 21, so the late Earl tried the experiment, and succeeded in April 1851 in getting the number up to 48. The late Mr. E. P. Shirley,[2] in November 1873, recorded 27; the late Rev. John Storer,[3] in July 1874, found 25, and apparently an increase of two or three in the December following. In June

[1] This was no doubt the 'big calf, eight or nine months old,' seen by Storer on August 6, 1875 (*Wild White Cattle*, pp. 258 and 259).

[2] Storer, *Wild White Cattle*, p. 220.

[3] *Loc. cit.* p. 222.

1877, Mr. A. H. Cocks [1] found the number reduced to 20. Mr. J. R. B. Masefield,[2] whose visit was apparently about 1884, remarks that 'a few years ago the number was reduced to 17'; but at the time of his visit the number was 28, and three had been recently killed. Mr. E. de Hamel,[3] in May 1886, found 30.

This herd's existence seems to be traceable further back even than Chillingham—namely, to 1248–49, according to Sir Oswald Mosley ('Hist. Tutbury, co. Stafford,' 1832).

The colour is uniform—white, with black noses, ears and feet, sometimes ticked. Occasionally black calves are born, but are not kept. An old tradition says that the birth of a black calf means a death in the family of Ferrers.

The number of calves reared annually would average about half the number of breeding cows.

There is no evidence or knowledge of fresh blood having at any time been introduced.

Lay cows were formerly admitted to the park, and crosses with the wild bulls obtained, but this was stopped twenty years ago. The result of these crosses was very good meat, but the cross-breds were very awkward to milk or handle.[4]

The animals in this herd are heavier in front and lighter behind than any of the other herds; in general shape and character, both of bodies and horns, they closely resemble the old domestic breed of Staffordshire longhorns.

The udders of the cows are remarkably small, and incline forwards at an angle—very unlike the huge gland of a domestic cow.

In winter the cattle are fed on hay in sheds.

The park is nearly 1,000 acres, and is in its natural, original condition. It has never been manured, or broken up, or seeds sown, and contains a very great variety of wild plants.

Vaynol.—In August the herd consisted of 53 animals—namely, 1 old bull, 2 young ditto, about 20 cows, and about 30 heifers and calves of both sexes.

They are short-legged, straight-backed animals, all white with black muzzles, black tips to the ears, and more or less black about the hoofs, varying, however, in individuals, some being only faintly marked in this way. They all have horns, not very long, sharp, and turned up at the ends, but not quite uniform.

In winter they are fed with hay, but are never housed, and none of the cows are ever milked. The beef is of excellent quality.

The original importation of this herd from Kilmory took place in 1872, consisting of 22 head—namely, 1 bull, 9 cows, 6 heifers rising two years, 6 yearling steers.

In May 1882 the herd numbered 37 or 38, including 8 young calves, and 1 bull, which would be killed when three years old.

In August 1886 the remainder of the Kilmory herd were brought here

[1] *Zoologist*, 1878, p. 276.

[2] *Proceedings N. Staffordshire Naturalists' Field Club*, 1885, p. 33.

[3] *Handbook prepared for the use of the British Association when visiting Birmingham*, 1886

[4] A heifer calf was born in 1875 out of a domestic cow by a wild bull; the heifer was said to resemble the wild animals very closely. Seen in the distance the clear white, characteristic of the young of the park herds, was conspicuous.

—namely, 2 yearling bulls, 14 cows and heifers, 8 two-year-old heifers, 8 yearling heifers; 32 in all.

The average number of calves born per year (previous to the addition of the remainder of the Kilmory herd) was about 14, of which perhaps half a dozen were reared, the remainder being killed for veal.

Some time within six or eight years of the first instalment of cattle coming to Vaynol a black bull calf was born.

Very few deaths occur, and only among the calves, of which now and then one dies of 'scouring.'

The cattle, although never handled, nor housed in winter, are not fierce, and will allow a near approach (except when they have calves) without showing any signs of impatience or alarm.

Since the arrival of this herd at Vaynol in two instalments, no fresh blood has been introduced, nor have any exchanges been effectual; nevertheless, Mr. Assheton-Smith is of opinion that the cattle have improved both in size and weight.

Sir John Orde [1] says that, shortly before he parted with the herd, he obtained two young bulls from Hamilton, with a view to changing the blood, but they proved quite useless, and both met with accidents and had to be destroyed.

Sir John Orde wished to have fresh blood, owing to an opinion that the cattle were deteriorating in bone and horn from close breeding, and also slightly in fertility.

The origin of the Kilmory herd, as gathered by Storer, is that the late Sir John Orde in 1838 purchased a bull, the only survivor of the Duke of Buccleuch's (Dalkeith) section of the old Athol herd. This was used with Kyloe (West Highland) cows, carefully selected. After some few years this bull and Lord Breadalbane's (Taymouth) were exchanged, and the latter was used with good results until 1852, when a West Highland bull calf was bought, and this sire was supposed to have much improved the stock. No further crosses were made up to the time Mr. Storer's book was published, 1879; but since then the present Sir John Orde, in the above quoted letter, says that they had had at various times, crosses with ordinary Highland, Ayrshire, and Indian cattle. The first named was the only one found desirable, the produce of some cows recently, that proved infertile with the wild bull, being very satisfactory in everything except colour; the cattle show traces of their Kyloe extraction.

About 200 acres of the park are allotted to the cattle, consisting of old (artificial) pasture, bordering a lake. This run is shared by red and fallow deer, and there are a few roe deer in the plantations round the park, descended from Scotch and German stock. A doe was seen in the middle of August last with two fawns.

Blickling.—In July last this herd comprised :—Bulls: 1, five years old; 2, two years old; 1 calf. Cows: 9; 2 yearling heifers; 6 calves. Total, 21.

Only the two young bulls and the two heifers were in the park; the others were kept up.

Storer says that these cattle were introduced from Gunton about the beginning of the present century, and that they were nearly destroyed a few years since by the rinderpest, which killed off all but three or four, and since then the herd has been somewhat made up, and consequently somewhat altered in its characteristics.

[1] Letter, dated June 1 1887.

The cattle here are black-pointed (muzzles, ears, and hoofs); sometimes the points are red; sometimes there is no colour about them at all. They are frequently spotted like flea-bitten Arab horses. The six heifer calves born this year are irregular in their markings. Two have black ears, but no spots; while one has red ears, and the other has white ears.

All calves with black points are preserved, amounting to about five or six in a year. The herd is low at present—only numbering about twenty altogether, ranging from five years old to calves of this year.

There has been a large proportion of bull calves during the last year or two. The individual animals are finer at the present time than when Mr. Storer made his report, but they are not as large as they were previous to the rinderpest, which destroyed the whole herd except a few calves.

By the advice of Mr. Storer a cross was obtained from Somerford, two young bulls being sent thence, one of which had an incipient horn. There was another cross about five years ago with a cow from Yorkshire, which in appearance was like the cows in the Blickling herd—it was out of a white shorthorn by a black Galloway.

No horns have appeared among its descendants, though one cow always throws black calves (which are never reared), and in some of the others the black points have been more than usually pronounced.

As soon as the animals are adult, and are taken into the dairy herd, they no longer range in the park, but are fed in meadows. The land is light, and they are given cotton cake all through the summer; in winter this is supplemented by hay, but no roots are given. In cold weather they are housed at night.

Woodbastwick.—The herd in August last contained:—1 bull; 12 cows, aged from nine to two years; and about the same number of young animals.

Ten calves have been born this year, of which three have died.

There is also a white shorthorn bull, which was used for breeding purposes last year.

Originally all these cattle had red ears and red muzzles. Latterly, however, from want of fresh blood, it has been impossible to maintain the red points. A red-pointed bull, received in exchange from Somerford (about 1879), proved useless. Mr. Cator was therefore obliged to use a black and white bull sent from Somerford, which had (as was supposed) some black Angus blood in him. The stock by this strain have nearly all had black points, though some few have them of a dark chocolate colour, and a few others are red pointed.

This bull had a good deal of black on his back, and the calves at first took after him, being in most cases more or less spotted with black. As he got older, however, the calves took after the cows, and in 1883, which was the last year he was used, all the calves came pure white, with black ears and noses.

The next bull used was a son of the last, and the result was satisfactory as regards markings, although more calves were black- than red-pointed.

The present bull is a son of this one, and is a splendid animal and beautifully marked. Though a little light behind, as all this breed seem to be, they are very heavy in the withers.

At different times some three or four different shorthorn bulls have been used, the last occasion being last year (1886). This was done with a view to improving the hindquarters, which are rather light. They are

inclined to be weak in the loins, and their coats had been getting very fine. This last cross has not proved very successful as regards marking, all the calves turning out pure white, ears and all, and a few will have horns, while the character of the head differs from the old type, which was short, and broad between the eyes. The cattle, from interbreeding, had become delicate and thin in the coat, but the shorthorn cross has much improved the coat. The white of the shorthorn looks yellow by the side of the pure white of the park breed.

Though the cattle are not considered hardy, they are good milkers when well fed.

This herd originated from Gunton stock. Storer says that the late Mr. A. Cator bought one cow at a sale about 1840.[1] This cow produced a bull calf, and at various times subsequently the herd was recruited by red-pointed calves from Blickling.

The cattle here are kept in fields, and do not enjoy the wider range of a park. The soil is poor and gravelly. They are stalled all the winter and fed on turnips. In the exceptionally protracted bad weather of last winter they were given oil cake in addition.

In conclusion, the Committee request that the thanks of the British Association be conveyed to the following noblemen and gentlemen for the assistance they have kindly rendered in the preparation of this Report, and that a copy of this Report may be forwarded to each of them :—

The Dowager Marchioness of LOTHIAN, Blickling Hall, Norwich.
The Earl FERRERS, Chartley Castle, near Stafford.
The Earl of TANKERVILLE, Chillingham Castle, Belford, Northumberland.
Sir JOHN W. P. CAMPBELL-ORDE, Bart., Kilmory, Loch-Gilp-Head, N.B.
Sir CHARLES W. SHAKERLEY, Bart., C.B., Somerford Park, Congleton, Cheshire, and his Agent, J. HILL, Esq., Smethwick Hall, Congleton.
G. W. DUFF-ASSHETON-SMITH, Esq., Vaynol Park, Bangor, N. Wales.
A. CATOR, Esq., Woodbastwick Hall, near Norwich, and his son JOHN CATOR, Esq., Woodbastwick Hall, near Norwich.
D. C. BARR, Esq., Chamberlain to his Grace the Duke of Hamilton, Hamilton, Lanarkshire.

Report of the Committee, consisting of Professors SCHÄFER (*Secretary*), MICHAEL FOSTER, *and* LANKESTER, *and* Dr. W. D. HALLIBURTON, *appointed for the purpose of investigating the Physiology of the Lymphatic System.*

THE Committee appointed for the purpose of investigating the physiology of the lymphatic system are not at present able to present a complete report; the chemical physiology of the lymphatic glands is the only subject upon which they feel prepared this year to make a definite communication. This investigation has been carried out in the Physiological Laboratory, University College, London, by Dr. Halliburton. The following is his report :—

The animals employed in the research have been mostly cats; in a few cases the lymphatic glands of dogs have been also examined, which entirely corroborate the more complete observations upon cats' glands. The method employed in the research was as follows :—The animal was

[1] Mr. A. Cator, the present proprietor, and son of the above, says in a letter, 'about the year 1832.'

chloroformed and killed by bleeding from the carotids; the thorax was then opened, and a cannula inserted into the aorta; a stream of salt solution ($\frac{3}{4}$ per cent.) was then passed at considerable pressure through the vessels by this means; in about a minute the large veins entering the heart were opened, and the mixture of blood and saline solution allowed to escape; in from five to ten minutes the vessels were entirely free from blood, and the fluid came through colourless. The abdominal glands were then removed, and dissected from surrounding fat and connective tissue; as much also of the capsule was removed as possible, and the glands were cut into small pieces, and ground up in a mortar with saline solution. By this means the lymph-cells were freed almost entirely from the remaining portions of the gland capsules, which were removed. The fluid, with the cells suspended in it, was poured into test-tubes, the cells in a short time settling to the bottom and forming a yellowish-white deposit. This process of settling was hastened by centrifugalising; the supernatant liquid was poured off, and the cells again washed with saline solution in a similar way. By this method the cells were quickly freed from any lymph which might still have been in contact with them. Microscopical examination of the cells showed that they still possessed their normal appearance, except for a small amount of shrinkage. The supernatant saline liquid was found to contain in small quantities the same proteids that were afterwards found in the cells, a certain amount of their proteid constituents having thus entered into solution.

The lymph-corpuscles collected by this means were further examined in order to determine qualitatively the kinds of proteids that they contained. Lymph-corpuscles being typical animal cells, this research was in other words directed to the determination of the varieties of proteid that occur in protoplasm.

The methods adopted for this investigation consisted in extracting the cells with various saline solutions, and then of examining these extracts by the methods of precipitation by neutral salts, and of fractional heat-coagulation.

Although it appears that this subject has not been investigated before in the same way, it should be mentioned that a very similar research was undertaken by Miescher [1] on the proteids of pus cells. He found that these cells contained five proteids, as follows:—

1. An alkali-albumin.
2. A proteid coagulable by heat at 48°–49° C.
3. Serum-albumin.
4. A proteid formerly considered to be myosin, which swells up into a jelly-like substance on admixture with solutions of sodium chloride.
5. A proteid insoluble in water, and in sodium chloride solution, and soluble with difficulty in dilute hydrochloric acid.

Miescher also investigated the properties and composition of the mucin-like substance called nuclein, which composes in main the substance of the cell nuclei, and which remains undigested in artificial gastric juice, and can be thus separated from the investing protoplasm. Although pus cells are in origin white blood corpuscles, yet on account of the degenerative changes they undergo while in an abscess cavity they

[1] Miescher, 'Ueber die chemische Zusammensetzung der Eiterzellen.' *Hoppe-Seyler, Med. Chem. Untersuchungen*, p. 441.

cannot be regarded as consisting of normal protoplasm. Many of the results obtained in this research, however, corroborate Miescher's facts.

The liquid which was found the best to dissolve the proteids of lymph cells was a partially saturated solution of sodium sulphate. Such a solution was prepared by mixing a certain volume of saturated solution of that salt with nine times its volume of distilled water. After thoroughly shaking the cells with this solution they dissolved to a very great extent, and microscopical examination of the *débris* showed that it consisted chiefly of nuclei, with apparently pieces of shrunken protoplasm adhering to or separate from the nuclei.

The proteids present in such an extract were as follows:—

1. A globulin which coagulates at 48°–50°. C.
2. A globulin which coagulates at 75° C.
3. An albumin which coagulates at 73° C.
4. An albumin which coagulates at 80° C.
5. Certain varieties of albumose and peptone.
6. A proteid similar to that described by Miescher in pus, which swells up into a jelly-like substance when mixed with solutions of sodium chloride and magnesium sulphate. It is the presence of this proteid which makes a solution of sodium sulphate a better liquid with which to extract the lymph-cells than either a solution of sodium chloride or magnesium sulphate, as sodium sulphate does not produce this peculiar phenomenon.

It will now be convenient to take these proteids one by one, and describe each in detail.

1. *The globulin which coagulates at* 48°–50° C.—On heating the sodium sulphate extract of the cells, faintly acidified with weak acetic acid, to 45°, the liquid becomes opalescent, and at 48° to 50° C. a distinct flocculent precipitate separates out. In one or two cases the temperature of heat-coagulation was somewhat higher, in one case as high as 55°. The precipitate, collected on a filter, has the usual characters of coagulated proteid. There are comparatively few proteids which coagulate at so low a temperature as this. The one which it most resembles is the proteid occurring in muscle plasma, which coagulates at 47°–48° C.; this proteid has been named paramyosinogen, and its properties are described elsewhere.[1] This proteid in lymph-cells resembles it in many particulars, but differs from it in certain others, which, however, are of minor importance. It resembles paramyosinogen in being a proteid of the globulin class, *i.e.* soluble in unconcentrated saline solutions, precipitable from them by dialysing out the salt from such solutions, and precipitable by excess of such a neutral salt as sodium chloride or magnesium sulphate. It differs from paramyosinogen in being precipitable with great readiness by weak acetic acid from its saline solutions, and in requiring for its complete precipitation with a neutral salt, like the above-mentioned, complete saturation with such a salt. The name I should propose for this proteid is cell-globulin α.

2. *The globulin which coagulates at* 75° C.—On heating the liquid from which cell-globulin α has been removed by heating to 50° C. and filtering, it becomes opalescent at about 66° C., and a flocculent precipitate begins to separate at about 73° C.; this is increased by heating to 75° C. This is because an albumin is present which coagulates at the former temperature, and a globulin at the latter. The temperatures are, however, so

[1] Halliburton, 'On Muscle Plasma,' *Journ. Physiology*, 1887.

close together that it is not possible to separate them by fractional heat-coagulation. The separation is effected as follows: the sodium sulphate extract is saturated with magnesium sulphate; this precipitates the globulins, leaving the albumins in solution. Magnesium sulphate also causes the swelling-up of the proteid numbered 6 in the foregoing enumeration of the proteids of lymph-cells; but on complete saturation with this salt, the swollen-up lumps become somewhat shrunken, and can be removed by filtration with the globulins. The precipitate on the filter is then washed with saturated solution of magnesium sulphate until the washings do not give the proteid reactions, and distilled water is then added to the filter. The salt adhering to the globulins enables them to dissolve in the water, while the jelly-like proteid remains undissolved. In this solution of globulins the α variety can be removed by heating to 50° and filtering, the second globulin remaining in solution. This second globulin, for which I should propose the name cell-globulin β, resembles serum-globulin in all its properties. It coagulates at 75° C., is precipitated by dialysis, is also precipitated completely by saturation with magnesium sulphate, and incompletely by saturation with sodium chloride. That white blood-corpuscles are a source of serum-globulin was first pointed out by A. Schmidt,[1] who showed that on their disintegration in shed blood, two of the products resulting are paraglobulin and fibrin ferment. The name paraglobulin is now almost abandoned; the term serum globulin is hardly applicable to a proteid existing in lymph-cells; hence it seems necessary to multiply terms and provisionally to designate this globulin by a new name.

3. *The albumin which coagulates at* 73° C.—This is present in small amount, being, on heating to 73°, often not more than a cloudiness in the liquid from which the globulins have been removed by saturation with magnesium sulphate and filtration. In those cases in which a larger amount than this was present, it was found to be identical in its properties with serum-albumin. It has been found, however, that the serum-albumin of warm-blooded animals can by fractional heat-coagulation be separated into α, β, and γ varieties coagulating respectively at 73°, 77°, and 83° C.[2] This albumin of lymph-cells is therefore identical with serum-albumin α; but, for the reasons just specified, it seems advisable here again to introduce a new term and provisionally to speak of this proteid as cell-albumin α.

4. *The albumin which coagulates at* 80° C.—This is, except for the difference in a few degrees of its heat-coagulation temperature, identical with serum-albumin γ. It is present in exceedingly minute quantities, and is often altogether absent. It may be named, in symmetry with the other proteids, cell-albumin β.

5. *Albumoses and Peptone.* — After filtering off all the foregoing proteids which are precipitable by heat, a certain amount of proteid material still remains in solution. This is not the peculiar mucinoid proteid to which allusion has already been made. That is carried down by and removed with the heat coagulum, as will be fully explained in the next section: but this proteid residue consists of albumoses, the name given by Kühne and Chittenden to those substances which are intermediate between ordinary proteids, and peptones. The amount of albumose, or perhaps proteose would be a better name, varies consider-

[1] Schmidt, *Pflüger's Archiv*, vol. vi. p. 445.
[2] Halliburton, 'Proteids of Serum,' *Journ. of Physiology*, 1885.

ably. In some cases a doubtful trace is all that is present: in other cases the amount is considerable, the precipitate produced by adding nitric acid being a fairly thick cloud. On examining the matter more closely, it was found that in those preparations rapidly made from glands removed immediately after death, the amount of albumose was all but imperceptible; while in those which had been allowed to remain for an hour or more at a summer temperature before they were extracted with a saline solution, the amount was more considerable. The same result was obtained by preparing these albumoses in another way: the glands from several cats were chopped up finely, and placed under absolute alcohol for four months; by this means the ordinary proteids were rendered insoluble; the glands were then dried over sulphuric acid, and powdered. Aqueous extracts of this powder contained no proteids which were coagulable by heat, but varying quantities of albumose. In those cases in which the glands had been removed with great expedition and placed immediately under alcohol, the amount of albumose present was very small; but in those in which there had been delay, the amount of albumose was considerable, and was easily separated into proto albumose (*i.e.* an albumose precipitable by nitric acid in the cold, the precipitate dissolving on the application of heat, and reappearing when cooled, not precipitable by dialysis, and precipitated by saturation with sodium chloride) and deutero-albumose (*i.e.*, an albumose which is not precipitated by dialysis, nor by saturation with sodium chloride, and which gives the nitric acid test just described only when its solution is saturated, or nearly saturated, with a neutral salt like sodium chloride). Hetero-albumose was not identified; it is exceedingly difficult to separate this substance from a mixture of proteids, as it is precipitated by heat, and converted into an insoluble albumose—dysalbumose—by alcohol. In only one case was peptone present; in all other cases, no proteid remained in solution after saturating the solution with ammonium sulphate; that is, peptone was absent.

These observations suggested that the presence of these substances was due to some post-mortem change in the proteids of the protoplasm. This surmise was strengthened by the further observation that, although the natural reaction of the lymphatic glands is alkaline, in a very few minutes, usually under a quarter of an hour after death, they become faintly acid. A. Hirschler[1] has shown that this acid is sarko-lactic acid. Brücke showed that pepsin is present in various tissues, and accounted for its presence by saying it was absorbed from the alimentary canal. It does not exert any digestive function in the tissues because of their alkaline reaction. When, however, the reaction of a tissue becomes acid, there is no reason why, as in this case, the ferment should not exert its proteolytic action. That this explanation is probably the correct one, was shown by a few experiments performed as follows: the glands were quickly removed from the animal, cut into small pieces, and then divided into two halves; one half was extracted immediately with a weak solution of ammonium sulphate; this extract was saturated with ammonium sulphate, and the precipitate so produced filtered off. The filtrate contained no peptone, and the precipitate contained a mere trace of proto-albumose. The other half of the glands was placed in distilled water; on testing the reaction of this half an hour later, it was found to be distinctly acid; thymol was added to prevent putrefaction, and the whole kept in an

[1] A. Hirschler, *Zeit. Physiol. Chemie*, vol. xi. p. 41.

incubator at 36° C. for six hours. The pieces of gland were then filtered off, and the filtrate saturated with ammonium sulphate; the precipitate so produced was collected on a filter. The filtrate contained abundance of peptone, and the precipitate contained a small amount of deutero-albumose; the action having presumably been sufficiently great, so that digestion had advanced beyond the proto-albumose stage.

6. *The mucin-like proteid.*—This proteid, which was first described by Miescher in the protoplasm of pus cells, is also present in the cells of lymphatic glands. It forms, in fact, the largest proteid constituent of those cells. When the cells are extracted with a five- or ten per cent. solution of either sodium chloride or magnesium sulphate, the result is a slimy mass, very much resembling mucus in its appearance. It may be obtained free from other proteids by pouring this mixture into a large excess of distilled water; this peculiar proteid then extends in cohesive strings throughout the water, and in time these contract and settle at the bottom of the water. This is then washed by decantation with $\frac{3}{4}$ per cent. sodium chloride solution, in which it is very slightly soluble.

The following are its chief properties:—

(*a*) It is insoluble in water.

(*b*) It is slightly soluble in $\frac{3}{4}$ per cent. sodium chloride solution. If the lymph-cells be extracted with this solution, a small amount of all the proteids described goes into solution, and among them this one. Such an extract is not, however, slimy; it becomes slimy when the proportion of salt is increased to a strength of 5 per cent.

(*c*) When a 10 per cent. sodium chloride solution, with this proteid in suspension, is heated to 50° C. the mucus-like strings shrink, and can be easily filtered off. In the case of sodium sulphate extracts of glands it is apparently carried down with the cell-globulin α, which coagulates at this temperature. When the sodium chloride solution is boiled, the shrunken flakes which formed at 50° C. break up and dissolve; they are not, however, reprecipitated on cooling. It is, however, precipitated once more when poured into water, and also by the addition of acetic acid.

(*d*) Saturation with neutral salts. Saturation of a sodium sulphate extract of cells with sodium sulphate causes little or no precipitation of the proteids contained therein; nor does it cause any mucinous appearance. In a very weak sodium chloride solution ($\frac{3}{4}$ per cent.), there is also no mucin-like appearance; this only comes on when the strength of the solution reaches 5 per cent.; saturation with sodium chloride causes a small amount of shrinkage of this proteid, and renders filtration easier. Magnesium sulphate acts in a similar way. Ammonium sulphate acts similarly; saturation with this salt, however, causes the proteid to lose almost altogether its resemblance to mucin, and precipitates it as whitish flakes.

(*e*) It is precipitable by absolute alcohol, by basic lead acetate, by dilute sulphuric acid, and by solution of tannin.

(*f*) It is precipitated by acetic acid in strings like mucin; like mucin it is also soluble in baryta or lime-water; from which solution it is again precipitable by acetic acid, and not soluble in moderate excess of that reagent.

It is thus seen that this substance is very like mucin in its reactions, and in its physical characters. The question arises: Is it mucin? The substance nuclein, of which the cell-nuclei are made up, has been described as very similar to mucin; but it is not this substance with which we have

to deal, as the cell-nuclei are exceedingly insoluble, and are not attacked at all by such reagents as $\frac{3}{4}$ per cent. sodium chloride; this proteid, which assumes a mucinoid appearance on treatment with sodium chloride, is undoubtedly a constituent of the cell protoplasm: and the question, Is it mucin? is not an idle one, as the degeneration of cell protoplasm into mucin is one which is constantly taking place, in such situations as the submaxillary gland, or the epithelium cells of the respiratory and alimentary tracts, to form goblet cells.

I think, however, that this proteid is not mucin, but only resembles it in certain physical characteristics, as well as in a few tests: it is precipitated by tannin, which does not precipitate mucin; the best proof, however, of its identity or non-identity would be an elementary analysis; this I have not made as yet. My present chief ground for believing this substance not to be mucin is that it is not a glucoside, like mucin, or at least that prolonged boiling with sulphuric acid does not cause it to yield any substance which has a reducing action on cupric hydrate. I look upon this substance as a globulin, but one which is much more readily precipitated by neutral salts than most other globulins are; a proportion of 5 per cent. of sodium chloride, for instance, in its solutions rendering it insoluble. The precipitate, moreover, is not of the usual fine flocculent character, but a slimy, mucus-like one. In my investigation on muscle plasma, I showed that the precipitate of the proteid called myosinogen is of a similar slimy appearance, though to a much less degree. The name I propose for this proteid is mucinoid globulin.

The question which I have in the last place investigated is whether there exists in lymph-cells any substance like myosin. Myosin is the substance which separates from muscle plasma after death, in the same way that fibrin separates from blood plasma. In the case of muscle this coagulation is accompanied by the formation of a lactic acid. Now we have in the case of the lymph cells seen that there is a formation of acid; is there any simultaneous formation of a solid proteid analogous to myosin or fibrin? I have tried to answer this question by experiments similar to those by which Kühne obtained muscle plasma from frogs, and which I have lately extended to mammals. But hitherto this question has been answered in the negative. By employing strong pressure upon the glands frozen immediately after removal from the body, I have been able to express from them a juice; but one, however, which underwent no spontaneous coagulation on exposure to a temperature of 35°–40° C. Similarly extracts of the frozen glands with solutions of sodium sulphate of various strengths, did not undergo coagulation when subsequently diluted to various extents with water, and exposed in an incubator to the temperature of 36° C. In other words, such experimental methods that enable one to study the coagulation of blood or of muscle, lead in the case of the lymph-cells to an entirely negative result. Miescher in his examination of pus cells came to an exactly similar conclusion.

This research is at present incomplete; up till now all that has been attempted is a separation and recognition of the various proteids in the cells which can be extracted by saline fluids. A very important point is the determination of the influences these various constituents have upon the coagulation of the blood, on account of some recent observations by Dr. Wooldridge. To this question I hope to be able next year to apply myself.

W. D. HALLIBURTON.

Second Report of the Committee, consisting of General J. T. WALKER, General Sir J. H. LEFROY (*Reporter*), Professor Sir W. THOMSON, Mr. ALEXANDER BUCHAN, Mr. J. Y. BUCHANAN, Mr. JOHN MURRAY, Dr. J. RAE, Mr. H. W. BATES (*Secretary*), Captain W. J. DAWSON, Dr. A. SELWYN, *and* Professor C. CARPMAEL, *appointed for the purpose of reporting upon the Depth of Permanently Frozen Soil in the Polar Regions, its Geographical Limits and Relation to the present Poles of greatest cold. Drawn up by* General Sir J. H. LEFROY, *R.A.*, *K.C.M.G.* (*Reporter*).

THE Committee have received a valuable communication from Dr. Percy Matthews, LL D., coroner for the North-west Territories of the Dominion of Canada, and resident medical officer at York Factory, on Hudson's Bay, of which an analysis is subjoined:—

York Factory, lat. 57° N., long. 92° 26′ W. (No. 9 of Report of 1886). Surface about 51 feet above sea-level.

I. *Positive Evidence of the Depth of Penetration of Frost.*

(1) 1879–1886. By the mean of seven measurements in the channel of Hayes river, at the mouth of which the factory is situated. Thickness of ice in January, February, and March, 6 feet 6 inches. Hayes river has been, on the average of the last thirty years, closed to navigation on November 26, and reopened on May 17.

	No.	Alluvial Soil. Inches	Superficial Thaw. Inches	Frozen Soil. Inches	
(3) April 14, 1885	514	22	None	33	Boring continued to 17 feet. Very dry soil.
(4) May 4, 1886	17	21	2	48	Boring continued to 17 feet. Wet soil. 20 inches of snow on surface.
(5) May 28 „	519	21	$2\frac{1}{2}$	40	Wet soil.
(6) June 4 „	521	23	7	30	Boring continued to 18 feet. Dry soil.
(7) June 23 „	526	21	14	31	Boring continued to 18 feet.
(8) June 25 „	527	—	65	68	A stratum of 3 inches of frozen water was found at 65 inches, resting on clay.[1]
(9) June 26 „	528	—	14	96	Boring continued to 21 feet.[2]
(10) July 23, 1881	14	20	28	38	Boring continued to 10 feet. Dry soil.

[1] The MS. gives 'frost penetration 3 inches,' with the explanation, 'a lodgment of 3 inches of frozen water over clay bed at 65 inches.' Evidently, therefore, the frost had got down 68 inches. The boring was continued to $18\frac{1}{2}$ feet.

[2] Dr. Matthews adds the following note to this observation:—Taken in a clearing, the barest and most bleak in the neighbourhood of York. It is nearly at all times

(2) 1882–83. By the mean of 485 measurements made in the course of a survey of the bed of Nelson river (about seven miles north of York Factory), under direction of Mr. H. Jukes, C.E., for the Winnipeg and Hudson's Bay R.R. Company. Thickness of ice, or penetration of frost, in December, January, and February, 5 feet 10 inches.

On July 1, 1886, the soil of No. 528 was only thawed 20 inches, and in another spot within the clearing, $37\frac{1}{4}$ inches. On September 6 following, at 140 yards north of this spot, the soil was frozen to a depth of 102 inches, with 51 inches of thawed ground at the surface. And at 140 yards south of the same spot to a depth of 94 inches, with 42 inches of thawed ground (Nos. 602, 603). Other measurements of the thawed ground, September 4 and 10, gave respectively 50 and 52 inches.

II. *Examples of Excavation or Boring without finding Frozen Soil, and of Superficial Thaw.*

1870, August, September. In excavating a dry dock at York no frost down to 36 feet.

1879, August 25. Nos. 8–10. 300 yards W.; 300 yards N.W.; 300 yards S. of York. In a swamp, no frost found down to 33 feet.

1880, August 10. Nos. 11–13. 100 yards S.; 300 yards S.; and 100 yards S.W. as before. No frost found down to 33 feet.

1882, August 30 (see below, Severn river).

„ September 10. Nos. 16–22. Six graves opened in an old Indian burial-ground. Depth of alluvial soil 48 inches. No frost down to 10 feet. The burial-place in question has been disused for fifty years, and the results in surrounding ground which has never been disturbed are the same.

1884, July 30. Nos. 519–513. Four graves opened; depth of alluvial soil 40 inches. Thin sandy clay; no frost down to 16 feet.

1886, May 28. No. 518. In a garden at York, thaw $7\frac{1}{2}$ to 9 inches.

Landslips, Hayes River.

1884, July 15. No. 509. The thawed soil was 36 inches in depth.

1885, June 18. No. 515. The thawed soil was 29 inches in blue clay, 37 inches in white clay.

1886, June 14. No. 523. The thawed soil was 28 inches.

1883, Sept. 10. No. 508. On a much exposed portion of the bank of Hayes river, dry soil, there was no frost down to 16 feet.

The following are also given as observed depth of thaw in or near York Factory, that of the frost below not having been measured.

freed from its winter's snow by the action of fierce winter gales sweeping over Hudson's Bay. So that its soil is fully exposed to the greatest degree of frost-penetration possible, not only from above downwards, but from its position, laterally; therefore, having selected this, the most exposed site obtainable, I had a trench dug 10 feet in length down to the non-frozen subsoil. This experiment, together with subsequent ones, is in my opinion conclusive, inasmuch as I consider it indicates the greatest depth of frost-penetration in and around York of late years, and may certainly be ranked as perpetual ice, but upon a scale so small as to be wholly comprised, as far as my experience goes, within ten acres. To give an idea of quarrying in frozen ground in June, I may mention that I had an Indian working hard for three days to obtain the above information.

1886, May 28. No. 518. Garden at York, in dry soil, $7\frac{1}{2}$ inches; in wet soil, 9 inches.
,, May 31. No. 520. In a swamp 1,000 yards south of the factory, 10 to 12 inches.
,, June 14. No. 525. Garden at York, average 18 inches.
,, July 1. No. 529. In the swamp, 36 inches.
,, ,, 3. No. 531. After two days' rain, 37 inches.
,, Aug. 2. Nos. 533–545. In the swamp, 48 inches, 12 borings.
,, ,, 2. Open ground, 40 inches, 9 borings.
,, ,, 15. Nos. 555–570. In the swamp, 49 inches, 15 borings.
,, ,, 20. Nos. 571–583. ,, 56 ,, 12 ,,
,, ,, 25. Nos. 584–596. ,, 11 feet 12 ,,
,, Sept. 1. Nos. 597–600. ,, 15 ,, 3 ,, after heavy rain.
,, ,, 8. Nos. 604–607. ,, 30 ,, 3 borings.

The general summary of the author from eight years' observation is—

The greatest depth at which the soil was found frozen was 102 inches.
,, ,, ,, of thaw having frozen soil below it was 52 inches.
,, ,, ,, reached without finding frost, 33 feet.
The mean temperature by nine years' observations is 17·4° F.
Mean rainfall 22·98 inches.
,, snowfall 47·91 ,,

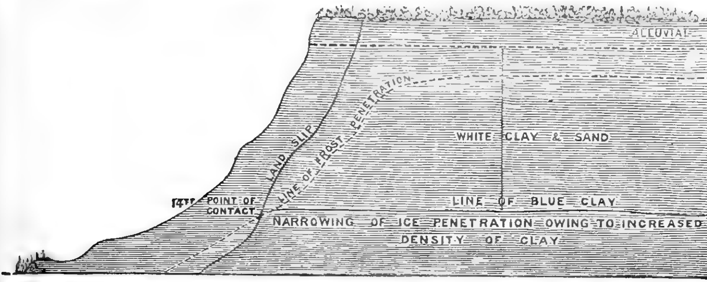
1882–83. At the river Severn, lat. 56°, or 1° south of York Factory, in making a cutting for a jetty, in December and January, no frost was found at 15 feet down. It is not stated how far it *was* frozen (as it must have been nearer the surface).

To his tabular statement the author has added the following 'Notes on the table of experiments for ascertaining the depth of frost and thaw penetration, York Factory, Hudson's Bay':—

'In briefly examining the accompanying list of experiments, it will at once be realised that so many variable conditions have to be taken into consideration in connection with frost-penetration that it is impossible to form any estimate other than that based upon a series of experiments carried over a number of years. For, in the first place, the extent of the winter's frost must be dependent upon locality (including soil, exposure, drainage), season, and certainly, from my experience, upon the snowfall, be it early or late, much or little; even as the depth of the summer's thaw, though subject in a negative sense to like conditions, is to a great extent dependent upon the rainfall. For instance, reverting to six experiments (Nos. 14, 514, 517, 519, 521, 526) carried out in the York churchyard (a site which is protected by surrounding willows, palisading, &c., and so thoroughly in the lee that, when the country lying beyond is bare, it maintains its covering of certainly 20 inches of snow throughout the winter), the soil is there found to be frozen to an average depth of three feet only, whereas, within 350 yards, Experiments Nos. 528, 602, and 603 tell us that under exactly opposite conditions a depth of upwards of eight feet of frost is attained. Again, on the same principle, if the snowfall is late, the soil will naturally be found to be frozen far deeper than when it early covers the ground, even as the rainfall, if great during the summer, inde-

pendently of season, exercises a considerable influence in determining both the rapidity and penetration of the thaw.

'In venturing to offer some explanation of Sir John Richardson's statement "that the soil was found frozen to a depth of nearly 20 feet at York Factory," apart from the consideration of it being a severe season, which it undoubtedly was (for on referring to old records I find that the winter of 1834–35 was exceptionally severe), I would in all deference submit, from observations of my own upon this point, that the measurement alluded to gave but a section of the lateral freezing of a landslip; for in sounding the "face" of a perpendicular bank, say 40 feet in height, for frost-penetration, the frost will be found at its depth in relative proportion to the height of the bank, making all due allowance for the varying of its penetrative action in differing strata; but if the bank be not perpendicular, but sloping, the frost follows the declivity, and a portion of the thawed surface (probably due to heavy rains) slides over the frozen subsoil, and, impinging on the denser structure, abruptly breaks off at the point where the frost-action is checked, and gliding on thus exposes a



Rough Diagram of Landslip in Hayes River: apparent frost-penetration of over 14 feet proved to be only 4 feet.

thawed surface, leaving a deceptive frost-line far below the true one, which upon a cursory examination leads to the supposition that the ice-penetration is greater than it really is. Though this is conjecture as regarding the statement in question, I have the rather endeavoured to illustrate not only what I have witnessed myself, but that which may be an explanation of the depth of frost alluded to in this particular instance.[1]

'But in further reference to Sir John Richardson's statement "that the soil was found frozen to a depth of nearly 20 feet at York Factory," I must not omit the fact that Mr. George Gladman, a chief factor of the Hudson's Bay Company's service, in his evidence before the Select Committee of the House of Commons in 1857, says, "Pits were dug there (York) with a view of ascertaining the depth of ground thawed during summer; repeated diggings showed about three feet of thawed ground, whilst the perpetually frozen ground was found to be fifteen feet deep." In this connection, although fully admitting its corroborative force, I cannot but point out a discrepancy of nearly five feet (4 feet 10 inches)

[1] It is to be observed of the above diagram that if the line of fracture, instead of being only some four or five feet back from the edge of the bank, had been twice or thrice that distance, the whole frozen part would have disappeared and the section have disclosed the real depth of the frost, provided the slip occurred, as they usually do, at a period of the year too advanced for the new face to freeze to any depth.

existing between Sir John Richardson's experiment and those carried out by Mr. Gladman, *the same year*, plainly indicating that the site of Sir John Richardson's experiments must have been exceptional, as I have before inferred. In passing on to Mr. Gladman's experiments, it must be noted that the climate of York has undergone a considerable change, even within the last fifty years; indeed, quoting from Mr. Gladman's later evidence, he says that "turnips and garden-stuff failed at York on account of the nearness of the sea, the severity of the seasons, and summer frosts." Whereas now, speaking from a personal experience of upwards of eight years, I may say that no difficulty whatever exists in providing the establishment with very passable potatoes, excellent turnips, and several kinds of "garden-stuff," and that many kinds of flowering plants thrive in the open air. The country surrounding York fifty years ago was thickly wooded, and more swampy than it now is; evidence of its being so is present to-day in the innumerable grassy hillocks dotted around the settlement, formed by the decayed stumps of trees forced up out of the ground by the compressive action of frost. Therefore, under these altered conditions, not only would the frost-penetration be deeper, the thaw be less, but "perpetual ice" would extend at a greater depth over a much larger area than it now does. Something may also be attributed to a disposition which prevailed among the older generation of fur-traders to minimise the suitability of the North West for agricultural settlement.

'I am not in a position to offer any very satisfactory explanation as to the frost-penetration being so relatively small at York, considering the mean temperature of the year, beyond stating that the surrounding country contains numerous springs, which may be readily tapped at any time during the winter; that the subsoil is clay, though this perhaps hardly bears upon the question when closely examined. Doubtless the inconsiderable height above the sea-level, and "the immediate vicinity of a large body of unfrozen water," are important factors, and do exercise a great influence upon the surrounding country, although I must not omit the more immediate bordering of some miles of frozen water for upwards of five months in the year. As to whether the peaty formation of much of its soil has any appreciable influence in absorbing and accumulating the intense tropical heat of summer is a question beyond my humble ken; but that the frozen subsoil acts as a "provision" in the earlier part of summer in counteracting the effects of such heat as regarding vegetation is a fact that can be, in my opinion, incontestably proved in some parts of the country immediately surrounding York.'

In a second communication, dated July 27, 1887, Dr. Matthews, in answer to questions, reiterates his belief that no permanently frozen ground now exists at York Factory, with the slight qualifications stated on p. 152:—

'The climate has unquestionably changed, and the surface vegetation equally. The presence of grass, superseding moss, of itself would materially influence frost-penetration, but with the drying up of the country, owing to many causes (uprising of the land, &c.), the frost-penetration would be less. The surface vegetation is, in my opinion, a more important factor than water.'

He quotes Indian testimony as well as comparison of records to prove that the rivers open about a week earlier and close about a week later than they did 50 years ago.

The Committee are indebted to Dr. J. Rae for the following communication:—The station in question is only a little north and east of No. 20 in the first report.

Ice in Ground.—By Frederick C. Baker, Binscarth, Manitoba.—Twenty-three observations taken in the prairie lands of Manitoba. Approximate position—lat. 50° 40′ N., long. 101° 20′ W.; east of Assiniboine river.

Q. How deep does frost penetrate the ground, and how is depth affected by greater or less quantity of snow on ground?

A. On May 20 last year (1886) frost was found whilst digging a cellar 5 feet below surface. High ground near a prairie. In June 1883, whilst digging a cellar of the Binscarth Company's store, frost was met with at a depth of 9 feet.

On April 20 last year (1886) we drove fence-posts 2 feet into ground without touching frost.

Cannot say exactly how far depth of snow affects penetration of frost, but our creek got frozen to the bottom this winter (1886–87) for want of a good supply of snow on first ice; therefore suppose that want of snow on ground would facilitate the deeper penetration of frost.

Dr. Rae adds here:—'From my own knowledge, the bottom of pools which have been in winter frozen to the bottom, remain solid ice for a long time after much of the ice is thawed out of the land not covered by water.'

Q. Have you heard of or seen any frost in ground in autumn? If so, how far down in the earth has it been?

A. Never heard of any of the old stock of ice remaining so long.

Q. At what time of the year does the ground become quite free from frost?

A. If you mean for farming operations, ploughing can generally be got at between April 10 and 15.[1]

Q. How far have you usually, in your district, to dig for water?

A. Everything depends upon the locality. When shale is known to be underground, water is sure to be got when it is reached, and good water too; seams of shale vary as to their depth. Wells range from 9 to 200 feet in depth. A well of the latter depth (200 feet) has just been dug at Birtle (March 1887), on the Manitoba and N.W. Railway, through *all clay*; but it is on the high banks of the Birdtail river or creek, where a person would expect to have to go deep. At Binscarth station the well is 84 feet deep through clay; this is also near the banks of a creek My well is now 61 feet, also on the bank, with the creek 64 feet below. We struck a very slight spring at this depth, which gives us only about six inches of water, through a hard clay. We intend going down until a good spring is reached, which we expect to find below the level of the creek, *at least*. So much for the deep wells.

I know lots of wells about here from 9 to 40 feet. I think one may say the average is 30 feet.

There is never much difficulty in getting water at a reasonable depth on the ordinary level prairie *about here*. During the summer of 1883 we used water from a well not over six feet deep, but that was not a dry year.

Q. Do you know any explanation of the working of the willow in finding springs?

[1] That is not what was meant.—[J. Rae.]

A. Both the openings of the well of Birtle and Binscarth were found by this method, and a number of others.[1]

This evidence that Rhabdomancy has sincere believers in the Canadian prairies is not without curiosity.

No expense has been incurred. The Committee recommend that they be reappointed.

Report of the Committee, consisting of the Rev. Canon CARVER, *the* Rev. H. B. GEORGE, Sir DOUGLAS GALTON, Professor BONNEY, Mr. A. G. VERNON HARCOURT, Professor T. MCKENNY HUGHES, *the* Rev. H. W. WATSON, *the* Rev. E. F. M. MCCARTHY, *the* Rev. A. R. VARDY, Professor ALFRED NEWTON, *the* Rev. Canon TRISTRAM, Professor MOSELEY, *and* Mr. E. G. RAVENSTEIN (*Secretary*), *appointed for the purpose of co-operating with the Royal Geographical Society in endeavouring to bring before the authorities of the Universities of Oxford and Cambridge the advisability of promoting the study of Geography by establishing special Chairs for the purpose.*

THE Committee beg leave to report that, at a meeting held on January 12, 1887, at the office of the Association, the following resolutions were adopted:—

1. That the Committee fully recognise the educational value of the scientific study of geography, and are agreed in thinking that geography should occupy a place among the subjects of study at the Universities of Oxford and Cambridge.

2. That the Council of the British Association be requested to give their support to the representations and offers made to the Vice-Chancellors of the two Universities by the Council of the Society in letters dated July 9 and December 9, 1886, of which copies are enclosed.

London: July 9, 1886.

MY DEAR VICE-CHANCELLOR,—The Council of the Royal Geographical Society have on two previous occasions (in 1871 and 1874) addressed memorials, of which copies are enclosed, to your predecessors, urging the claims of geography to further recognition by the Universities.

They have recently undertaken an inquiry into the position of geography in English and Continental education. The result has been unfavourable to England; and there has been a general concurrence of testimony, according with their own strong conviction, that the most effectual step towards the removal of our inferiority would be the establishment in our Universities of Chairs or Readerships similar to those held in Germany—viz., by Karl Ritter at Berlin, and Professors Peschel and Richthofen at Leipzig.

So much of human knowledge and human interests is bound up with the relations and interaction of the physical conditions of the earth, the study of which is practically embraced in geography, that there are few

[1] This is scarcely an answer to the question. As both these wells were deep (84 and 200 feet) *possibly* water might have been found at these depths without the 'willow method' being used to discover the spring.—[J. RAE.]

branches of education which do not present a geographical aspect, and which do not therefore offer a field for instruction in geography in combination with some other subject.

It is unnecessary to insist upon the close connection of history and geography, or upon the importance of a knowledge of the physical conditions of the various regions of the world, to those who engage in the conduct of our political affairs.

Without the comprehensive study of the earth, for which Englishmen, as a people, have the largest opportunities and the least preparation, physical students would fail to grasp the true character and relations of the various sciences of observation, such as anthropology, geology, botany, meteorology, &c.

As geography already holds a statutable place in the studies of the University, it seems to us that the courses of a Reader or Professor in Geography might easily, by consultation with the examiners, be so arranged as to fit in with the requirements of scholars in the Honour Schools, their establishment serving rather to complete the present University system of instruction than to introduce a new element into it.

The Council of the Royal Geographical Society are so fully convinced of the national importance of placing geographical science on a sound footing, and of the necessity of some action at the Universities in order to obtain this result, that they have approved the proposals submitted by their Education Committee, enclosed herewith, which they beg you to take into your favourable consideration, and to submit at the earliest opportunity to the proper authorities.

The length of time for which the Society should undertake to make a contribution out of its funds towards a Geographical Chair or Readership will be further considered whenever your University may be prepared to accept our proposition in principle, and to discuss in detail the plans proposed.

Believe me, my dear Vice-Chancellor,

Sincerely yours,

ABERDARE, *President.*

To the Vice-Chancellor of the University of Oxford.

December 9, 1886.

SIR,—The Council of the Royal Geographical Society have on two previous occasions (in 1871 and 1874) addressed memorials, of which copies are enclosed, to your predecessors, urging the claims of geography to further recognition by the Universities.

They have recently undertaken an inquiry into the position of geography in English and Continental education. The result has been unfavourable to England; and there has been a general concurrence of testimony, according with their own strong conviction, that the most effectual step towards the removal of our inferiority would be the establishment in our Universities of Chairs or Readerships similar to those held in Germany—viz., by Karl Ritter at Berlin, and Professors Peschel and Richthofen at Leipzig.

So much of human knowledge and human interests is bound up with the relations and interaction of the physical conditions of the earth, the study of which is practically embraced in geography, that there are few branches of education which do not present a geographical aspect, and

which do not therefore offer a field for instruction in geography in combination with some other subject.

It is unnecessary to insist upon the close connection of history and geography, or upon the importance of a knowledge of the physical conditions of the various regions of the world, to those who engage in the conduct of our political affairs.

Without the comprehensive study of the earth, for which Englishmen, as a people, have the largest opportunities and the least preparation, physical students would fail to grasp the true character and relations of the various sciences of observation, such as anthropology, geology, botany, meteorology, &c.

It seems to us that the courses of a Reader or Professor in Geography might easily, by consultation with the examiners, be so arranged as to fit in with the requirements of scholars in the Honour Schools, their establishment serving rather to complete the present University system of instruction than to introduce a new element into it.

The Council of the Royal Geographical Society are so fully convinced of the national importance of placing geographical science on a sound footing, and of the necessity of some action at the Universities in order to obtain this result, that they have approved the proposals submitted by their Education Committee, enclosed herewith, which they beg you to take into your favourable consideration, and to submit at the earliest opportunity to the proper authorities.

The length of time for which the Society should undertake to make a contribution out of its funds towards a Geographical Chair or Readership will be further considered whenever your University may be prepared to accept our proposition in principle, and to discuss in detail the plans proposed. A similar proposal has already been laid before the Vice-Chancellor of Oxford, and is now under the consideration of the Hebdomadal Council.

I am, &c.,

(Signed) RICHARD STRACHEY, *Vice-President.*

To the Vice-Chancellor
of the University of Cambridge.

Final Report of the Committee, consisting of General J. T. WALKER, General Sir H. LEFROY, Sir WILLIAM THOMSON, Mr. ALEX. BUCHAN, Mr. J. Y. BUCHANAN, Mr. H. W. BATES, *and* Mr. E. G. RAVENSTEIN (*Secretary*), *appointed for the purpose of taking into consideration the combination of the Ordnance and Admiralty Surveys, and the production of a Bathy-hypsographical Map of the British Islands.*

1. YOUR Committee desire to draw attention to the absolute necessity of making the contours of the land and of the adjoining ocean-bed to correspond with each other. The method of drawing contours on the land at one set of intervals and on the sea at another set is objectionable and unscientific, more especially if the land and sea contours are referred to different datum planes.

2. With reference to maps of particular localities on a larger scale,

your Committee are of opinion that the existing Ordnance maps should be utilised. A combination of the Ordnance map with the Admiralty charts presents no difficulties, and in doubtful or difficult cases a co-operation of our two Survey Departments would speedily lead to satisfactory results.

Your Committee are happy to be able to report that Sir Charles Wilson, the present Director of the Ordnance Survey, is arranging to insert contours showing the configuration of sea bottom upon the contoured edition of the one-inch Ordnance map, and is prepared to extend this system to the whole of the Survey as soon as the means necessary for that purpose shall have been granted by Government. This extension will necessitate a certain amount of bathymetrical survey for delineating the beds of lakes and river channels which has not yet formed part of the operations of the Ordnance Survey.

3. With reference to general maps on small scales, the Secretary of your Committee has prepared contoured maps of the Loch Linnhe region (including Ben Nevis), and of the country on the Lower Medway, these two districts presenting the extreme features which have to be taken into consideration when preparing a bathy-hypsographical map of the whole of the British Islands. These maps have been tinted experimentally.

4. Your Committee are of opinion that no adequate representation of the vertical configuration of the lowlands, the lower hill ranges, and of the ocean-bed can be obtained on the proposed scale of 1 : 200,000 unless the contours, up to a height and down to a depth of 1,000 or 1,200 feet, are drawn at intervals not exceeding 100 feet. In some localities it may even become necessary to introduce supplementary contours. These contours, whether they refer to the land or to the ocean-bed, would have to be referred to a fixed datum level, such as that of the Ordnance Survey of Great Britain.

In the more mountainous parts of the country, contours at intervals of 500 feet (as on the one-inch Ordnance map) appear to yield fairly satisfactory results.

5. The larger lakes would have to be contoured as if they had been drained, a faint horizontal shading indicating their character as lakes.

6. In some foreign maps (including the new one of the United States, on a scale of 1 : 250,000) the contours are printed in brown, and by this means a fair idea of the configuration of the land may be obtained, especially if the intervals between the contours are small.

7. Your Committee are, however, of opinion that the intelligibility of he proposed map would be very much increased by the employment of tints. In selecting these tints it must be borne in mind that the map is to embrace the whole of the British Islands with the surrounding seas, and that a system of colouring suited to the highlands might utterly fail when applied to the more gentle undulations of the greater part of the country. It may at once be admitted that none of the systems of tinting employed or suggested hitherto has proved thoroughly satisfactory.

8. The 'natural' method of tinting a map of this description, and that which most readily suggests itself, is to apply one colour to the sea and another to the land, and either to increase the depth of the tints with the height (or depth), or to apply the deepest tints to the least elevated parts of the country. A reference to Maps 1 and 2 proves that very fair results are attainable by this method. In the one case the lowlands and valleys are emphasised; in the other the mountain-tops become the most prominent points on the map. When tinting a map in this way

care must, of course, be taken that even the deepest tints do not obscure the underlying outline and lettering.

In practice it will be found that this system of tinting, whilst thoroughly applicable either to a country of hills or to a mountain region, is not well suited to a map embracing both low hill ranges and lofty mountain chains. On a map of the British Islands tinted on this system the lower hill ranges would merge almost completely into the surrounding plains, so as to be hardly recognisable.

9. Hence a 'regional' system of tinting has generally been applied to maps of countries presenting great variety of surface configuration. If we apply distinct colours, presenting striking contrasts, to each stratum of elevation, as in Map 5, the various strata or regions can be readily traced, but the map assumes a highly artificial appearance, and hence we are unable to recommend this arbitrary system of colouring.

10. It appears to us that all practical and scientific requirements can be met by limiting the number of regions to be distinguished by colours.

On Maps 3 and 6 only two regions are distinguished, viz., lowlands up to 500 feet, and the more elevated parts of the country. The former are shown in five shades of green, the latter in brown, growing paler with the elevation.

On Map 7 three regions are distinguished, viz., lowlands up to 500 feet, shown in green; hills and uplands, between 500 and 1,000 feet, shown in orange or red; and the mountainous regions, which are coloured brown, the depth of colour increasing with the height.

A yellow tint is introduced on Map 8 for lowlands up to 100 feet; the effect, however, is far from pleasing.

We believe that a map tinted on the principle adopted in Maps 4 and 7 would best meet all reasonable requirements.

11. Should it be desired, for special reasons, to distinguish a larger number of regions, the tints of Map 9 recommend themselves for adoption. In this instance the colours of the prism have been employed in regular succession, viz., brown, red, orange, yellow, and green for the land, and blue, indigo, and eventually violet and lavender-grey for the sea. This succession of colours, whilst presenting fair contrasts easily caught by the eye, affords at the same time a natural gradation from the darker to the lighter tints, supposing, of course, that the shades of the various colours employed are judiciously selected.

It should be stated that the specimen maps which accompany this report have been coloured by hand, and that maps tinted by the lithographic process would present better facilities for identifying each tint by a reference to the scale of colours attached to the map.

12. One other method of colouring hypsographical maps remains to be attended to, viz., the employment of a double scale of tints—one for valleys and level ground generally, the other for uneven ground. This system has been applied with much effect to maps of the Alps, but its application to the whole of the British Islands would undoubtedly lead to confusion and indistinctness. In our opinion the contrast between even and uneven ground could be more clearly exhibited by shading the hills on the system in ordinary use.

13. The map should not be crowded with names. Altitudes and depths—the former in upright, the latter in sloping characters—should be freely and judiciously inserted.

14. Your Committee think it desirable that the bathy-hypsographical

map should be accompanied by a general map, showing boundaries and political features, and engraved on the same scale.

15. Your Committee are of opinion that the production of a bathy-hypsographical map of the British Isles, such as they recommend, together with that of an accompanying political map, both on the scale of 1 : 200,000 (about three miles to the inch), should be left to private enterprise, the production of maps on a larger scale being entrusted to the Ordnance Survey Department.

[A set of the nine maps designed by Mr. E. G. Ravenstein in illustration of this report can be seen in the library of the Royal Geographical Society.]

Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Secretary*), Professor ARMSTRONG, Mr. STEPHEN BOURNE, Miss LYDIA BECKER, Sir JOHN LUBBOCK, Bart., Dr. H. W. CROSSKEY, Sir RICHARD TEMPLE, Bart., Sir HENRY E. ROSCOE, Mr. JAMES HEYWOOD, *and* Professor N. STORY MASKELYNE, *appointed for the purpose of continuing the inquiries relating to the teaching of Science in Elementary Schools.*

YOUR Committee, in continuing their periodic reports upon this subject, have to state that nothing has been done this year in the shape of actual legislation, but that great advance has been made in regard to the public appreciation of the importance of scientific and technical instruction.

The only alteration in the code of this year that at all bears upon the matter is that drawing is withdrawn from the list of class subjects, which gives an advantage to the claims of geography and elementary science by removing a powerful competitor in those schools that can only take two class subjects.

The return of the Education Department for this year shows that the diminution previously noted in the teaching of science subjects still continues.

The statistics of the class subjects for four years are given in the subjoined table, which shows an actual decrease in geography and elementary science, notwithstanding the increase in the number of departments examined. It will be seen that drawing begins to figure in this year's return, but the effect of it will be much more apparent in that for next year.

Class Subjects	1882-3	1883-4	1884-5	1885-6
English . . . (Departments)	18,363	19,080	19,431	19,608
Geography . . ,,	12,823	12,775	12,336	12,055
Elementary Science ,,	48	51	45	43
History . . . ,,	367	382	386	375
Drawing . . ,,	—	—	—	240
Needlework . . ,,	5,286	5,929	6,499	6,809
	18,524	19,137	19,266	19,522

The return of passes in the scientific specific subjects on the individual examination of children shows again an actual falling off in the total, and either an actual or relative falling off in every subject except Mechanics, A. The large increase in the teaching of mechanics is due to the carrying out of the peripatetic method of teaching it by the School Boards of Liverpool, Birmingham, Nottingham, and London. The figures are given in the following table:—

Specific Subjects	1882–3	1883–4	1884–5	1885–6
Algebra . . . (Children)	26,547	24,787	25,347	25,393
Euclid and Mensuration ,,	1,942	2,010	1,269	1,247
Mechanics, A . . ,,	2,042	3,174	3,527	4,844
,, B . . ,,	—	206	239	128
Animal Physiology . ,,	22,759	22,857	20,869	18,523
Botany . . . . . ,,	3,280	2,604	2,415	1,992
Principles of Agriculture ,,	1,357	1,859	1,481	1,351
Chemistry . . . ,,	1,183	1,047	1,095	1,158
Sound, Light, and Heat ,,	630	1,253	1,231	1,334
Magnetism and Electricity ,,	3,643	3,244	2,864	2,951
Domestic Economy . ,,	19,582	21,458	19,437	19,556
	82,965	84,499	79,774	78,477
Number of Scholars in Standards V., VI., VII.	286,355	325,205	352,860	393,289

The rapid and serious decrease of attention paid to these science subjects is shown by the percentage of children who have passed as compared with the number of scholars that might have taken these subjects, viz.:

In 1882–3	. . . . . .	29·0 per cent.
,, 1883–4	. . . . . .	26·0 ,,
,, 1884–5	. . . . . .	22·6 ,,
,, 1885–6	. . . . . .	19·9 ,,

and it must be remembered that when children have passed in two of these subjects they count twice over.

Of course a good deal of scientific instruction is given in many elementary schools under the name of object lessons, not only in the infants', but also in the boys' and girls' departments; but this is neither examined by Her Majesty's inspector nor encouraged by a grant except in the few cases where it comes in as a class subject under the name of elementary science. These object lessons are therefore very apt to be neglected. The same remark applies in the case of pupil teachers. It may be worthy of record that in the pupil teachers' schools of the London Board natural history and the principles of physics are taught systematically in the junior division, and this year an examination has been held by the Board inspectors, and certificates of proficiency are to be awarded.

The Royal Commission appointed to inquire into the working of the Education Acts of England and Wales issued their first report in August last, from which it appears that two of the points of inquiry bore directly upon the scope of this Committee. The one was 'Elementary Science: to what extent can it be taught in elementary schools?' The other, 'Technical Instruction: as grants are made in girls' schools for needle-

work, why not for mechanical drawing and handicraft in boys' schools?' Another instalment of the evidence was issued in June last.

With reference to the first-named subject of inquiry, Her Majesty's inspectors and others who were examined appear not only of opinion that elementary science is of importance, but some maintain, with Matthew Arnold, that 'Naturkunde should be a necessary part of the programme.' Most of them agree with the view expressed by this Committee, that the absolute preference given to English as a class subject should be abolished, and the choice thrown perfectly open.

With reference to the second subject of inquiry, the evidence of Sir Philip Magnus, Dr. Crosskey, Mr. Hance (Clerk to the Liverpool School Board), and others is distinctly in favour of it, showing that it is both desirable and practicable.

It appeared to your Committee that the British Association should contribute its views on these subjects to the Royal Commission, and they accordingly passed a resolution to that effect. This met with the approval of the Council. Two of the members of the Committee have since given evidence. The Rev. Dr. Crosskey enforced strongly the importance of elementary science and technical instruction, and more recently Sir Henry Roscoe, as the mouthpiece of the Committee, presented a series of the reports of this Committee and a memorial emphasising the two points of special importance, viz., as to the absolute preference given to English, and as to the want of provision for ensuring the instruction of pupil teachers in any kind of elementary science. The memorial also repeated their approval of the recommendation of the Royal Commission on Technical Instruction, 'That proficiency in the use of tools for working in wood and iron be paid for as a specific subject, arrangements being made for the work being done, so far as practicable, out of school hours. That special grants be made to schools in aid of collections of natural objects, casts, drawings, &c., suitable for school museums.'

An important meeting of gentlemen interested in popular education was held at the house of Mr. George Dixon at Birmingham last November, at which some of your Committee were present. This has led to several courses of action. The resolutions come to at this meeting were adopted in the following form by the School Board for Birmingham:—

I. That it is desirable that an enabling Bill should be introduced into Parliament to give School Boards power to provide and maintain schools in connection with the Science and Art Department, in which a course of instruction extending over a period not exceeding three years may be given in accordance with its regulations, such schools to be open only to scholars who have passed the sixth standard in public elementary schools.

II. That in Article 113 of the Code of Regulations of the Education Department, affecting evening schools, Paragraphs IV., V., and VII. of sub-section (b) should be omitted. These paragraphs read thus:—'IV. No scholar may be presented for examination in the additional subjects alone. V. No scholar may be presented for examination in more than two of the additional subjects. VII. Scholars presented for examination in the third or fourth standard, if they take one additional subject, must take English; if they take two, the second subject must be drawing, geography, or elementary science.'

III. That the words in Article 13 of the Code of Regulations of the

Education Department, which exclude scholars who have passed the seventh standard from the number of grant-earning scholars, and also the words in the Instructions to Her Majesty's Inspectors which bear on this part of the said article of the code, should be expunged.

These were afterwards brought before the Education Department on December 14 by a deputation of the Birmingham, Leicester, and Nottingham Boards, which was unofficially joined by members of the London Board. Two Bills have been brought into Parliament, and have passed their first reading. The one introduced by Sir Henry Roscoe relates to technical education (day schools), and embodies the substance of the above resolution, No. 1. The other is introduced by Professor Stuart, and relates exclusively to evening continuation schools, embodying the substance of Resolution No. 2. Sir Richard Temple, the Vice-Chairman of the London School Board, also propounded a scheme by which technical and commercial instruction might be given in Board Schools. Quite recently the Government have brought in a Bill dealing with the same subject, which has been read the first time.[1]

In consequence of the Government having given notice of their intention to introduce such a bill this session, Mr. George Howell withdrew the resolution of which he had previously given notice—'That in the opinion of this House it is essential to the maintenance and development of our manufacturing and agricultural industries, in view of the rapidly increasing competition of other nations, both at home and abroad, and in consequence of the almost universal abandonment of the system of apprenticeship, that our national scheme of education should be so widened as to bring technical instruction, the teaching of the natural sciences, and manual training within the reach of the working classes throughout the country.'

The Brighton School Board has opened an 'Organised Science School,' under the sanction of the Science and Art Department; but the official auditor has decided that all expenses incurred in respect of it are illegal, and has surcharged the Board with the balance not covered by the receipts. Appeal will be made to the Local Government Board against the decision of the auditor.

The experiment in manual instruction at Beethoven Street School was considered by the London School Board so successful that it was resolved to open five more classes of the same kind, but they were suspended in consequence of the official auditor having in the meantime surcharged the Board with the costs incurred for the workshop and tools. Appeal was made in November last against the surcharge of the auditor, but no answer has yet been received from the Local Government Board. The instruction is now being continued at Beethoven Street School, as a specific subject, with the concurrence of the inspector. That this subject finds favour with the elementary teachers is manifest from the fact that eighty of them have availed themselves of the opportunity offered by the City and Guilds of London Institute of qualifying themselves to give instruction in the use of tools, and many more applied who could not be accommodated.

The British and Foreign School Society have started a joinery class

[1] This Bill of Sir Wm. Hart Dyke was read a second time with little opposition, though with some suggestions of amendment; but it had to be abandoned on August 18, on account of press of business. It is intended, however, to proceed with the Scotch Bill.

at their Training College in the Borough Road, which is attended by all the senior students, in which instruction is given both in the theory and practice of carpentry.

The London School Board on May 19 adopted, by a very large majority, the motion of the Rev. C. D. Lawrence—'That, in the opinion of this Board, it is necessary to introduce into elementary schools some regular system of manual training,' and the matter was referred to a special committee on the subjects and modes of instruction in the Board's schools, which is now sitting.

The first examination by the Science and Art Department in the alternative first stage of chemistry has taken place, and may be considered to mark a great advance in the teaching of that subject. That the teachers were eager for such instruction is evident from the fact that as many applied for permission to attend Professor Armstrong's course of lectures established by the City and Guilds of London Institute as that institution could be made to accommodate.

There has recently been formed a 'National Association for the Promotion of Technical Education,' which includes the leading politicians who have given special attention to the subject of education. The following are the objects proposed :—

(*a*) The promotion in our primary schools of the better training of the hand and eye by improved instruction in drawing, in the elements of science, and the elementary use of tools.

(*b*) The introduction of such changes in the present system of primary instruction as may be necessary to enable children to take advantage of technical teaching.

(*c*) The more extended provision of higher elementary schools, where technical education may be provided for those who are fit to take advantage of it.

(*d*) The reform of the present system of evening schools, with special provisions for the encouragement of technical (including commercial and agricultural) instruction.

(*e*) The development, organisation, and maintenance of a system of secondary education throughout the country, with a view to placing the higher technical education in our schools and colleges on a better footing.

(*f*) The improvement of the training of teachers, so that they may take an effective part in the work which the Association desires to forward.

The Association was inaugurated at a meeting at the Society of Arts on July 1, when the Marquis of Hartington, who occupied the chair, was appointed President of the Association.

From this review of the present situation it would appear that the action of the Education Department tends positively to frustrate the efforts of those who desire to increase the teaching of natural science in elementary schools; but your Committee do not believe that that is the intention of those in authority, and feel sure that the great advance in public opinion will ultimately lead to a knowledge of the elements of science being made an essential part of all State-aided education.

Report of the Committee, consisting of Sir JOHN LUBBOCK, Dr. JOHN EVANS, Professor BOYD DAWKINS, Dr. ROBERT MUNRO, Mr. PENGELLY, Dr. HENRY HICKS, Dr. MUIRHEAD, *and* JAMES W. DAVIS, *appointed for the purpose of ascertaining and recording the localities in the British Islands in which evidences of the existence of Prehistoric Inhabitants of the country are found.* (*Drawn up by* JAMES W. DAVIS.)

THE objects sought to be attained by your Committee consist in recording and mapping the prehistoric remains of Great Britain; it is suggested that such remains may be best tabulated under the following groups:—

1. Caves and caverns.
2. Camps and earthworks.
3. Lake-dwellings and crannoges.
4. Menhirs and dolmens.
5. Barrows, tumuli, and other burial-places.

In mapping the localities of such remains it is proposed that distinctive signs shall be used to indicate the several groups.

Localised groups of objects formed in connection with the above or scattered over larger areas, such as flint or bronze implements, pottery, and other similar objects, may be classified, as far as possible, according to the following periods:—

1. Palæolithic stone age.
2. Neolithic stone age.
3. Bronze age.
4. Iron age.

It will be neither necessary nor possible to tabulate and record all the instances in which flint implements have been found, but it is suggested that records should be made of the discovery of hoards of implements, of localities where manufactories have been found, and in localities where the flints occur abundantly summarised lists of the objects should be given.

The information may be tabulated under the following heads:—

1. Object.
2. Locality.
3. Date when found.
4. If previously described cite authority.
5. Where the object is at present deposited.
6. Remarks.

The objects and information regarding them being necessarily of a very diversified character, it is difficult to suggest any form which shall meet every case, and the recorders will use a discretionary power in making their reports.

It is considered that the objects of the Committee may be best served by securing the assistance of one or more competent persons who shall represent a certain area-district or county, and record the occurrence in that area of any prehistoric objects which have been or may be found. The following gentlemen have kindly undertaken to form lists for the areas appended to their names:—

Professor G. A. Lebour, for Northumberland and Durham.
Rev. J. Magens Mello, for Derbyshire.
Capt. L. P. Oliver, for Hampshire.
W. Cole, Esq., Hon. Sec. Essex Field Club, for Essex.
Dr. Henry Laver, for Essex.
Thomas Boynton, Esq., Norman House, Bridlington, for East Riding, Yorkshire.
John Holmes, Esq., Leeds, for S.W. Riding, Yorkshire.
Dr. Robert Munro, for West Scotland.
William Horne, Leyburn, for Wensleydale.
Rev. C. H. Drinkwater, Shrewsbury, for Salop.
Dr. Henry Hicks, Hendon, London, for Wales.
Charles P. Hobkirk, Dewsbury, for West Riding, Yorkshire.

Lists have been received from Mr. Thomas Boynton of bronze implements, mostly in his own collection, found in the East Riding of Yorkshire, and from Mr. John Holmes a record of prehistoric objects has been received; both are appended. The remainder are being prepared, and there is much valuable material promised for a future report.

Your Committee will be glad to receive assistance from those interested in its objects, and consider that it is desirable that recorders should be connected with it in every county or district in the kingdom.

I.—*List of Bronze Implements, by Thos. Boynton, Bridlington Quay.*

N.B.—The numbers in the first column refer to the illustrations in Dr. Evans' 'Bronze Implements of Great Britain.'

Type	Name of Object	Locality	Date	Previous Description	Where Deposited	Length	Remarks
16	Celt . .	Staxton .	1886	—	Own Collection	4⅝ in.	Has ten waves on the blade and cable pattern on flanges.
12	" . .	Driffield .	—	—	"	3½ in.	The flanges are very slightly raised, and it has not the fluted pattern as described in Evans.
53	" . .	Gransmoor .	1862	—	"	7⅛ in.	Weight 21 oz.
50	" . .	Ulrome .	1879	—	"	5¾ in.	Has very slight stop ridge and plain blade.
55	" . .	"	—	—	"	5¼ in.	
56	" . .	Kilham .	1882	—	"	5⅜ in.	There is a slight vertical ridge on the lower part of the blade.
76	Palstave .	Leven .	—	—	"	5¼ in.	Pocketed at the stop ridge ½ in. deep.
55	Celt . .	Barmston .	1881	—	"	4¼ in.	The edge has been hammered out.
120	Socketed Celt	Leven . .	—	—	"	4 in.	Rim imperfect.
116	"	Gainsboro' .	—	—	"	4⅛ in.	
164	"	"	—	—	"	3¾ in.	
169	"	Harpham .	1876	—	"	3 in.	
125	"	Hutton-Hang	—	—	"	3⅛ in.	
125	"	Ulrome .	1877	—	"	3 in.	
136	"	Skipsea Brough	1885	—	"	4¾ in.	The chevron pattern is much closer than the Winwick specimen, and it has four horizontal lines on each side, like 138, Evans' 'Ancient Bronze Implements of Great Britain.'
398	Spear-head .	Ulrome .	1860	—	"	4⅛ in.	
394	" .	" . .	"	—	"	6¾ in.	

Type	Name of Object	Locality	Date	Previous Description	Where Deposited	Length	Remarks
405	Spear-head .	Brigham .	1880	Evans, 'Br. Impts.,' p. 327	Own Collection	$6\frac{3}{4}$ in.	Dr. Evans has erroneously described this as found near Lowthorpe.
382	" .	Leven . .	1885	—	"	$7\frac{1}{2}$ in.	Imperfect, the socket being broken.
395	" .	Skipsea .	1880	—	"	$4\frac{3}{4}$ in.	A portion of the shaft still in the socket.
401	" .	Carnaby .	—	—	"	$5\frac{1}{8}$ in.	There are traces of ornamentation on the socket, probably done with a chisel or punch. Unfortunately the boy who found it struck it against his plough and broke the point.
386	" .	Lake-dwelling, Ulrome	1882	—	"	$4\frac{1}{2}$ in.	Appeared to have been struck into the floor of the structure and broken from the shaft; a portion of the shaft (with the pin) yet remains in it. Caught by the workman's spade and broken.
114	Socketed Celt	Barmston .	1886	—	"	$2\frac{1}{2}$ in.	Found embedded in peat near the supposed site of a lake-dwelling. The top of the socket has been imperfectly cast, and it is filled with fragments of metal preparatory to recasting.
499	Button .	Near Beverley	—	—	"	1 in. diam.	The loop spans the entire diameter, and is bow-shaped. Plain, increasing in thickness downwards; circular.
—	Earring .	North Burton	1876	—	"	—	—
—	Bracelet .	Near Beverley	—	—	"	—	The bracelets are made of wire, plaited, and were purchased from Mr. Sumner's collection, Woodmansey, Beverley, described as being found in the locality.
—	" .	"	—	—	"	—	

II.—*List of Objects found near Leeds, by John Holmes, Roundhay, near Leeds.*

Object	Locality	Date when Found	Reference to previous Description	Where Deposited	Remarks
1. Urn . .	Broughton .	—	Thoresby, 'Ducatus Leodiensis,' p. 565	—	British; 10 in. in diameter.
2. Brass lance[1]	" .	—	" "	—	3 in. in length.
3. Hone[1] .	" .	—	" "	—	Bluish-grey stone; 3 in. in length.
4. Hammer[1] .	" .	—	" p. 566	—	6 in. in length; speckled marble, polished.
5. Bone implement[1]	" .	—	" "	—	Having holes bored in one end, and pointed like a bodkin at the other.
6. Urn . .	Leeds . .	1745	Wardell, 'Antiquities of Leeds,' 1853	—	12 in. in height; British, with rudely incised encircling rows of undulations.
7. Stone hammer	" . . .	"	" "	—	Found in the urn last mentioned; both are figured in the work cited.
8. Socketed celts	Bramham Moor	1709	Thoresby, 'Ducatus Leodiensis'	—	5 or 6 in number; ploughed up; 3 to $4\frac{1}{2}$ in. in length, 1 to $2\frac{1}{2}$ in breadth.

[1] Nos. 2, 3, 4, and 5 were found inside the urn No. 1.

TABLE II.—*continued.*

Object	Locality	Date when Found	Reference to previous Description	Where Deposited	Remarks
9. Celt . .	Bolton-in-Bolland	—	Thoresby, 'Ducatus Leodiensis,' p. 565	—	7 in. long, 2½ broad; bronze with lateral flanges; several similar ones have been found at Morley, near Leeds.
10. Celt, &c. .	Mixenden Moor, near Halifax	1776	Whitaker, 'Loides and Elmeti,' p. 373	—	A miscellaneous collection; bronze, with stone and other objects.
11. Bronze implements	Hunslet, near Leeds	1881	Holmes, 'Proc. Yorksh. Geol. & Polyt. Soc.' vol. vii. p. 405	Public Museum, Leeds	A hoard, consisting of 9 implements, under 10 ft. 6 in. of clay; there are 8 of the palstave and 1 of the socketed celt type.
12. Spear-head.	Hunslet . .	1878	” ”	” ”	1 mile S.E. of the preceding.
13. Bronze weapons	Churwell, near Leeds	1846	” p. 406	” ”	3 spears and 5 palstaves.
14. Palstave .	Morley . .	—	Wardell, 'Historical Notes,' p. 42, 1869	” ”	7 in. in length.
15. Palstave .	Churwell . .	—	Holmes, op. cit. p. 406	Museum Lit. and Phil. Soc. Leeds	Similar to palstaves in No. 11.
16. Bronze dagger	5 miles N.E. of Wakefield	1842	Holmes, 'Proc. Yorksh. Geol. & Polyt. Soc.' vol. vii. p. 406	—	At a depth of 22 feet beneath silt, &c., with oak trees.
17. Bronze dagger	Stanley Ferry .	1818	” ”	—	Together with solid oak canoe, now in the York Museum.
18. Bronze Celt	Wakefield, Sandal Magna	1852	—	Public Museum, Leeds	5⅝ in. long; early type, finely palmate.
19. Stag-horn pickaxe	Ilkley . .	1870	—	—	
20. Socketed & looped celt (bronze)	Roundhay, near Leeds	1880	—	Public Museum, Leeds	
21. Celt . .	Yeadon . .	1882	—	—	Others have been found near the same place.
22. Gold torque	” . .	1816	Denny, 'Proc. Yorksh. Geol. & Polyt. Soc.'	British Museum	
23. Bronze celt.	Wakefield .	1855	—	—	4 in. long; slightly flanged and well patinated.
24. Pottery .	Oulton . .	—	—	Rev. R. Burrell, Stanley, near Wakefield	British; pierced at the sides.
25. Bronze celt.	Leeds . .	—	—	Museum of Lit. and Phil. Soc. Leeds	Basalts.
26. Flint spear-head & arrow-heads	Adel, nr. Leeds	—	Thoresby, 'Ducatus Leodiensis,' p. 565	—	2 in. long, smooth, arrows barbed.
27. Urn . .	Halifax . .	—	F. A. Leyland, 'Rem. of Antiq. of Yorkshire,' p. 26, 1855	—	
28. Dagger .	—	—	Op. cit. p. 39 .	—	
29. Hammer .	Leeds . .	1870	—	Public Museum, Leeds	3 in. long, 2½ broad; associated with a number of black oak piles near the margin of the R. Aire.
30. Flint arrows, &c.	Ilkleymoor .	—	—	F. W. Fison, Esq., Ilkley	Numerous flint flakes are found, rarely associated with arrow-heads.
31. Arrow-heads, &c.	Adel, nr. Leeds	1865–1875	—	Museum Lit. & Phil. Soc., Leeds, and at Public Museum, Leeds	Flakes, arrow-heads, scrapers, &c., in large numbers; apparently a manufactory.
32. Hammer .	Potter-Newton, near Leeds	1879	—	Public Museum, Leeds	8¾ in. long by 3½ thick; two others found at same place.
33. Stone celt .	Shadwell . .	1881	—	—	4 in. by 2 in., beautifully worked and finished.

TABLE II.—*continued.*

Object	Locality	Date when Found	Reference to previous Description	Where Deposited	Remarks
34. Stone celt .	Roundhay, near Leeds	1884	—	Mr. Buckton, Leeds	4 in., cutting edge $2\frac{1}{2}$ in. decreasing to $1\frac{1}{2}$ in.
35. „ .	Patterton, near Leeds	—	—	Jno. Holmes, Roundhay	Similar to the two preceding.
36. Flint implements	Stanley Ferry, nr. Wakefield	1860–1887	'Remains of Antiq. in Yorksh.' Leeds, 1855	Rev. R. Burrell, Stanley, near Wakefield	Large numbers of arrow-heads, flakes, scrapers, and other objects.

Report of the Committee, consisting of General PITT-RIVERS, Dr. BEDDOE, Professor FLOWER, Mr. FRANCIS GALTON, Dr. E. B. TYLOR, *and* Dr. GARSON, *appointed for the purpose of editing a new Edition of 'Anthropological Notes and Queries,' with authority to distribute gratuitously the unsold copies of the present edition.*

THE Committee found that the cost of printing and publishing the first edition of 'Anthropological Notes and Queries' was defrayed partly out of the grant voted by the British Association for that purpose in 1874 and partly by General Pitt-Rivers, who edited the work. The first set of copies printed was paid for by the Association, and was exhausted a few years after publication. Additional copies being then required, they were printed at the expense of General Pitt-Rivers, who generously placed them at the disposal of the Association. It was for the distribution of what remains of these copies that the Committee had to arrange. Fifty of them have been placed at the disposal of the Anthropological Institute of Great Britain and Ireland for gratuitous distribution to such persons as the Council of that institute may deem advisable in the interests of anthropological research. Prof. Flower and Dr. E. B. Tylor have also undertaken to distribute copies to travellers and others willing and desirous to supply information wanted for the scientific study of anthropology at home. The Committee consider that the plan it has adopted for the distribution of unsold copies is such as will make the work more widely known than heretofore, and probably create a greater demand for the new edition when it is published than there might otherwise be.

The Committee, after carefully considering the question of how the preparation of the new edition can be most efficiently done, strongly recommend that the work be entrusted to the Anthropological Institute of Great Britain and Ireland. That being a body specially and permanently organised for the purpose of advancing the various branches of Anthropology, and, as such, having many facilities not possessed by a committee, as well as a Council which meets regularly, and at short intervals, during the greater part of the year, it is peculiarly well fitted to carry out the necessary arrangements for a thorough revision of the work, and after it is published to bring it under the notice of those for whom it is intended. The Committee have reason to believe that the Anthropological

Institute would be willing to undertake the task and to proceed with the work during the ensuing winter.

The Committee have not required to draw any of the money placed at its disposal last year by the Association, as its work has hitherto been entirely that of making preliminary arrangements.

The Committee ask to be reappointed, and, as during the course of next year money will be required for printing and publishing, they request that the sum of 50*l.* be placed at their disposal for that purpose. The sum asked for is the same as was contributed by the Association towards the publication of the first edition in 1874.

Third Report of the Committee, consisting of Dr. E. B. TYLOR, Dr. G. M. DAWSON, General Sir J. H. LEFROY, Dr. DANIEL WILSON, Mr. R. G. HALIBURTON, *and* Mr. GEORGE W. BLOXAM (*Secretary*), *appointed for the purpose of investigating and publishing reports on the physical characters, languages, and industrial and social condition of the North-western Tribes of the Dominion of Canada.*

THE following 'Circular of Inquiry' has been drawn up by the Committee for distribution amongst those most likely to be able to supply information:—

At the meeting of the British Association at Montreal in 1884 the subject of Canadian anthropology came frequently under public and private discussion. The opinion was strongly expressed that an effort should be made to record as perfectly as possible the characteristics and condition of the native tribes of the Dominion before their racial peculiarities become less distinguishable through intermarriage and dispersion, and before contact with civilised men has further obliterated the remains of their original arts, customs, and beliefs.

Two considerations especially forced themselves on the attention of anthropologists at Montreal: first, that the construction of the Canadian Pacific Railroad, traversing an enormous stretch of little known country on both sides of the Rocky Mountains, has given ready access to a number of native tribes whose languages and mode of life offer a field of inquiry as yet but imperfectly worked; secondly, that in the United States, where the anthropology of the indigenous tribes has for years past been treated as a subject of national importance, not only have the scientific societies been actively engaged in research into the past and present condition of the native populations, but the Bureau of Ethnology, presided over by the Hon. J. W. Powell (present at the Montreal meeting), is constituted as a Government department, sending out qualified agents to reside among the western tribes for purposes of philological and anthropological study. Through these public and private explorations a complete body of information is being collected and published, while most extensive series of specimens illustrative of native arts and habits are preserved in the museums of the United States, especially in the National Museum at Washington. If these large undertakings be compared with what has hitherto been done in Canada, it has to be admitted that the Dominion

Government, while they have taken some encouraging steps, as by the installation of an anthropological collection in the museum at Ottawa, have shown no disposition to make the study of the native populations a branch of the public service. Anthropologists have thus two courses before them in Canada—namely, to press this task upon the Government and to carry it forward themselves. Now it is obvious that agitation for public endowment will not of itself suffice, as involving delay during which the material to be collected would be disappearing more rapidly than ever. If, however, a determined attempt were at once made by anthropologists, resulting in some measure of success, public opinion might probably move in the same direction, and a larger scheme might, before long, receive not only the support of Canadians interested in the science of man, but the material help of the Dominion Government.

On these and other considerations the General Committee of the British Association appointed Dr. E. B. Tylor, Dr. G. M. Dawson, General Sir J. H. Lefroy, Dr. Daniel Wilson, Mr. Horatio Hale, Mr. R. G. Haliburton, and Mr. George W. Bloxam (Secretary) to be a committee for the purpose of investigating and publishing reports on the physical characters, languages, industrial and social condition of the north-western tribes of the Dominion of Canada, with a grant of 50*l*. This committee the next year sent in a 'Preliminary Report on the Blackfoot Tribes,' drawn up by Mr. Hale. Their action in other districts was, however, much delayed by the difficulty of making plans by correspondence, and the committee were reappointed at Birmingham in 1886, in the hope that during the ensuing year Mr. Hale might be able personally to visit some of the tribes.

It has now been arranged to collect information, as far as possible, over the vast region between Lake Huron and the Pacific, the materials thus obtained being edited and presented in successive reports, as they shall be from time to time received, by Mr. Hale, whose experience and skill in such research are certified to by his volume embodying the ethnography of the Exploring Expedition under Captain Wilkes and by his subsequent publications relating to Canada. As a means of obtaining data, the present memorandum has been drawn up for circulation among Government officers in contact with the native tribes, medical practitioners, missionaries, colonists, and travellers likely to possess or obtain trustworthy information. The results gained from the answers will be incorporated with those of a personal survey to be made in some of the most promising districts by the Rev. E. F. Wilson, who has been named on the recommendation of Mr. Hale, and will act under his directions.

Suggestions for Investigation.

Physical Characters.—Tables of anthropological measurements &c. from Canada being extremely deficient, schedules drawn up by medical men and other qualified anatomists and naturalists will be highly acceptable. The following headings comprise the chief points on which information is needed in this department: stature, girth, proportions of trunk and limbs, cranial indices, facial angle, &c., brain capacity, peculiar bodily forms and features, special attitudes and movements, muscular force, &c., colour of skin, eyes, and hair according to Broca's colour-tables, form and growth of hair, skin odour. Statistics are required as to age of maturity and decline, periods of reproduction and lactation, longevity. Especial import-

ance attaches to the examination of mixed races, especially crosses of North American Indian with European and African, the resemblances and differences between the offspring and the parent stocks, the number of generations during which inherited race-characteristics are distinguishable, and the tendency to revert to one or other of the ancestral types. Both as to native tribes and cross-breeds pathological observations are of value, as to power of bearing climate, liability to or freedom from particular diseases, tendency to abnormalities, such as albinoism &c., and the hereditary nature of abnormal peculiarities. Medical men have also better opportunities than others of observing artificial deformations practised by native tribes, especially by compression of the skull in infancy. Pacific North America has been one of the regions of the world most remarkable for this practice among the Flatheads (thence so named) and various other peoples; so that it may still be possible to gain further information on two points not yet cleared up, viz. first, whether brain-power in after-life is really unaffected by such monstrous flattening or tapering of the infant skull; and second, whether the motive of such distortion has been to exaggerate the natural forms of particular admired tribes, or, if not, what other causes have led to such ideas of beauty.

To those concerned in these inquiries it may be mentioned that the 'Notes and Queries on Anthropology' issued by the British Association contains a series of Broca's colour-tables, together with descriptions of the approved modes of bodily measurement &c.[1]

Senses and Mental Characters.—With the bodily characters of the Canadian tribes may advantageously be combined observations as to their powers of perception and ratiocination. The acuteness of sight, hearing, and smell, for which the wilder races of man are justly famed, may be easily tested, these being capabilities which rude hunters display readily and with pride, so that they may even serve as an easy introduction to other measurements and inquiries which savages cannot see the reason of, and reluctantly submit to. The observer's attention may be especially directed to settling the still open question, how far these sense-differences are racial at all, and how far due to the training of a hunter's life from infancy. As to mental capacity, among the means of convenient trial are to ascertain facility in counting, in drawing and recognising pictures and maps, and in acquiring foreign languages. Evidence is much needed to confirm or disprove the view commonly held that children of coloured races (Indian, negro, &c.), while intelligent and apt to learn up to adolescence, are then arrested in mental development, and fall behind the whites. Few points in anthropology are more practically important than this, which bears on the whole question of education and government of the indigenes of America, living as they do side by side with a larger and more powerful population of European origin. No amount of pains would be wasted in ascertaining how far mental differences between races may be due to physical differences in brain-structure, how far the less advanced races are lower in mind-power by reason of lower education and circumstances, and how far the falling-off at maturity in their offspring brought up with whites (if it actually takes place) may be due to social causes, especially the disheartening sense of inferiority.

Language.—Introductory to the investigation of language proper are

[1] This work is now out of print, and a new edition is being prepared by a Committee of the British Association, appointed in 1886.

certain inquiries into natural direct means of expressing emotions and thoughts. Preliminary to these are conditions of face and body which are symptoms of emotion, such as blushing, trembling, sneering, pouting, frowning, laughter, and smiles; there being still doubtful points as to how far all races agree in these symptoms, it is desirable to notice them carefully. They lead on to intentional gestures made to express ideas, as when an Indian will smile or tremble in order to convey the idea of pleasure or fear either in himself or some one else, and such imitations again lead on to the pretences of all kinds of actions, as fighting, eating, &c., to indicate such real actions, or the objects connected with them, as when the imitation of the movement of riding signifies a horse, or the pretence of smoking signifies a pipe. The best collections of gesture-language have been made among the wild hunters of the American prairies (see accounts in Tylor's 'Early History of Mankind,' and the special treatise of Mallery, 'Sign-language among the North American Indians'). There is still a considerable use of gesture-language within the Dominion of Canada as a means of intercourse between native tribes ignorant of one another's language, and any observer who will learn to master this interesting mode of communication, as used in the wild districts of the Rocky Mountains, and will record the precise signs and their order, may contribute important evidence to the study of thought and language. The observer must take care that he fully understands the signs he sees, which through familiar use are often reduced to the slightest indication; for instance, a Sioux will indicate old age by holding out his closed right hand, knuckles upward—a gesture which a European would not understand till it was more fully shown to him that the sign refers to the attitude of an old man leaning on a staff. The sequence of the gesture-signs is as important as the signs themselves, and there is no better way of contributing to this subject than to get a skilled sign-interpreter to tell in gestures one of his stories of travelling, hunting, or fighting, and carefully to write down the description of these signs in order with their interpretations.

Coming now to the philological record of native languages, it must be noticed that small vocabularies &c., drawn up by travellers, are useful as materials in more thorough work, but that the treatment of a language is not complete till it has been reduced to a regular grammar and dictionary. As to several Canadian languages this has been done, especially by the learned missionaries Fathers Barraga, Lacombe, Cuoq, and Petitot, who have published excellent works on the Ojibway, Cree, Iroquois, and Athapascan (Denedinjie) languages respectively; while Howse's Grammar is a standard Algonkin authority, and it is hoped that the knowledge of Mr. McLean and others of the Blackfoot language may be embodied in a special work. On the other hand, the study of languages west of the Rocky Mountains is in a most imperfect state. Nothing proves this better than the volume of 'Comparative Vocabularies of the Indian Tribes of British Columbia,' by W. Fraser Tolmie and George M. Dawson, published by the Geological and Natural History Survey of Canada. These vocabularies of the Thlinkit, Tshimsian, Haida, Kwakiool, Kawitshin, Aht, Tshinook, and other languages are important contributions to philology, well worth the pains and cost of collecting and printing; but the mere fact that it was desirable to publish these vocabularies of a few pages shows the absence of the full grammars and dictionaries which ought to be found. This want is felt even in districts where there are white

missionaries using the native languages, and native teachers acquainted with English, so that the necessary philological material actually exists, and only the labour of writing it down is required to preserve it from destruction. A general effort, if now made, would save the record of several dialects on the point of disappearance. It is suggested by the Committee that inquiry should be made for lists of words &c. hitherto unpublished; that the terms and phrases possessed by interpreters should be taken down; that sentences and narratives should be copied with the utmost care as to pronunciation and accent, and translated word by word.

Particular attention is asked to two points in the examination of these languages. Care is required to separate from the general mass of words such as have a direct natural origin, such as interjections expressing emotion, and words imitating natural sounds, as, for instance, the names of birds and beasts, derived from their notes or cries. It is desirable in such words to notice how close the spoken word comes to the sound imitated, for resemblances which are obvious from the lips of the native speaker are apt to be less recognisable when reduced to writing. It is also of interest to notice the significance of names of places and persons, which often contain interesting traces of the past history of families and tribes.

An ethnographic map, based on language, and showing as nearly as possible the precise areas occupied by the various tribes speaking distinct idioms, is a desideratum, and, if properly completed, will be an acquisition of the greatest value. Several partial maps have been published, mostly of the region west of the Rocky Mountains. Among these may be specially mentioned two maps by Mr. W. H. Dall, given in the first volume of the 'Contributions to North American Ethnology,' published by the United States Government—one of which relates to the tribes of Alaska and the adjoining region, and the other to the tribes of Washington Territory and the country immediately north of it. These are connected through British Columbia by the excellent map which accompanies the Comparative Vocabularies of Drs. Tolmie and Dawson. A small map, by Dr. Franz Boas, in 'Science' for March 25, 1887, with the accompanying report, adds some useful particulars concerning the coast tribes of that province. With the additions which different observers can supply for the various portions of the country, a complete tribal and language map of the whole Dominion might soon be constructed. In forming such a map, it is desirable that the various linguistic 'stocks,' or families of languages, completely distinct in grammar and vocabulary, should be distinguished by different colours. East of the mountains the number of these stocks is small, but west of them it is remarkably large. Besides showing the distinct stocks, the map should also show the several allied languages which compose each stock. Thus, of the widespread Algonkin family, there are in the territories west of Lake Superior at least three languages, the Ojibway, the Cree, and the Blackfoot, all materially differing from one another. If, in the proposed map, the Algonkin portion should be coloured yellow, the subdivisions in which these separate languages are spoken might be marked off by boundary lines (perhaps *dotted lines*) of another colour, say blue or red. It would be proper to give the areas occupied by the different tribes as they stood before the displacements caused by the whites. Following the example set by Gallatin in his Synopsis, it will be well to select

different dates for different portions of the map. The middle of the last century might be taken for Ontario, Quebec, and the Eastern Provinces, and the middle of the present century for the rest of the Dominion. If each observer is careful to give the tribal and linguistic boundaries in his own district, as he can learn them from the best informed natives and from other sources, the separate contributions can be combined into a general map by the editor of the report.

Arts and Knowledge.—The published information as to the weapons and implements, clothing, houses, and boats, and the rest of the numerous appliances of native life on both sides of the Rocky Mountains is not so deficient as the knowledge respecting other matters already mentioned; and their intellectual state, as shown in such arts as the reckoning of time, the treatment of wounds, &c., is also to some extent known from books of travel. Still every observant traveller finds something in savage arts which has escaped former visitors, and there are a number of points on which further inquiry is particularly invited. Though the practical use of stone implements has almost or altogether ceased, there are still old people who can show their ways of making them, and inquiry may probably show that stone arrow-heads, hatchets, &c., are still treasured as sacred objects, as is the case among tribes in California, who carry in their ceremonial dances knives chipped out of flint and mounted in handles —relics of the Stone Age among their fathers. Notwithstanding the general introduction of iron and steel tools by the whites, it is possible that something may still be learnt as to the former use of native copper and of meteoric iron (or iron supposed to be meteoric). With regard to native weapons, the spliced Tatar bow being usual in this part of America (having probably come over from Asia), it is desirable to examine further the modes of making and using it, the forms of arrows, &c. Any game-traps on the bow principle, if apparently of native origin, are worth describing, as possibly bearing on the early history of the bow. The art of cooking by water heated by dropping in red-hot stones having been characteristic of the western region, any traces of this should be noticed, while the native vessels carved out of wood or closely woven of fir root &c. are still interesting. The native mode of twisting or spinning thread or yarn, and the manufacture of a kind of cloth, not woven but tied across like that of New Zealand, require fuller description. Especial attention is required to the ornamental patterns of the region, which are of notable peculiarity and cleverness. To a considerable extent a study of them on hats and blankets, coats and pipes, &c., shows, in the first place, actual representation of such natural objects as men or birds, or parts of them, which have gradually lost their strictness and passed into mere ornamental designs; but the whole of this subject, so interesting to students of art, requires far closer examination than it has yet received, and especially needs the comparison of large series of native ornamented work.

Music and Amusements.—The ceremonial dances, especially those in which the performers wear masks and represent particular animals or characters, deserve careful description, from the information to be gained from them as to the mythology and religion embodied in them. The chants accompanying the dances should be written down with musical accuracy—a task requiring considerable skill, though the accompaniments of rattle and hollowed wooden drum are of the simplest. Several of the games played among the Indians before the coming of the Europeans are of interest from their apparent connection with those of the Old World.

This is the case with the ball-play, now known by the French name 'la crosse,' which belonged to the European game familiar to the French colonists. It is worth while to ascertain in any district where it is played what form of bat was used, what were the rules, and whether villages or clans were usually matched against each other. The bowl-game, in which lots such as buttons or peach-stones blackened on one side are thrown up, has its analogues in Asia; the rules of counting and scoring belonging to any district should be carefully set down. It is in fact more difficult than at first sight appears to describe the rules of a game so as to enable a novice to play it. Among other noticeable games are that of guessing in which hand or heap a small object is hidden, and the spear-and-ring game of throwing at a rolling object.

Constitution of Society.—Highly valuable information as to systems of marriage and descent, with the accompanying schemes of kinship, and rules for succession of offices and property, has in time past been obtained in Canada. Thus in 1724 Lafitau ('Mœurs des Sauvages Amériquains,' vol. i. p. 552) described among the Iroquois the remarkable system of relationship in which mothers' sisters are considered as mothers, and fathers' brothers as fathers, while the children of all these consider themselves as brothers and sisters. This is the plan of kinship since shown by Mr. L. H. Morgan to exist over a large part of the globe, and named by him the 'classificatory system.' J. Long also in 1791 gave from Canada the first European mention of the Algonkin *totem* (more properly *otem*), which has become the accepted term for the animal or plant name of a clan of real or assumed kindred who may not intermarry; for example, the Wolf, Bear, and Turtle clans of the Mohawks. These historical details are mentioned in order to point out that the lines of inquiry thus opened in Canada are far from being worked out. The great Algonkin family affords a remarkable example of a group of tribes related together in language and race and divided by totems, but with this difference, that among the Delawares the totem passed on the mother's side, while among the Ojibways it is inherited on the father's side. Some Blackfeet, again, though by language allied to the same family, are not known to have totems at all. To ascertain whether this state of things has come about by some tribes having retained till now an ancient system of maternal totems, which among other tribes passed into paternal and among others disappeared, or whether there is some other explanation, is an inquiry which might throw much light on the early history of society, as bearing on the ancient periods when female descent prevailed among the nations of the Old World. It is likely that much more careful investigation of the laws and customs, past and present, of these tribes would add to the scanty information now available. On the Pacific side of the Rocky Mountains, where the totem system and female descent are strongly represented, such information is even scantier; yet careful inquiry made before the passing away of the present generation, who are the last depositories of such traditional knowledge, would be sure to disclose valuable evidence. How large a field for anthropological work here lies open may be shown by a single fact. Among the characteristics of tribes, such as the Haidas of Queen Charlotte's Island, has been the habit of setting up the so-called 'totem posts,' which in fact show conspicuously among their carved and painted figures the totems of families concerned, such as the bear, whale, frog, &c. Such posts, which are remarkable as works of barbaric art, are often photographed, and Judge James G. Swan, of Port Townsend,

has published, in vol. xxi. of the 'Smithsonian Contributions,' an interesting study of them, as relating to episodes of native mythology, in which the animal-ancestors represented are principal figures. More investigation is required to work out this instructive subject, and with the help of the older natives will doubtless well repay the not inconsiderable trouble it will cost.

Among the special points to be looked to in the condition of the Canadian tribes both at present and previously to civilised influence may be noticed the modes of marriage recognised—whether the husband enters the wife's family or clan, or *vice versâ*; what prohibited degrees and other restrictions on marriage exist; what is the division into families, clans, and tribes; and how far do totems or animal names answer this purpose; what are the regulations as to position of first or chief wife, household life, separation or divorce; how relationship is traced in the female and male lines; rules of succession to chiefship and inheritance of property. It is desirable to draw up tables of terms of relationship and affinity in the native language according to the usual schedules, or by setting down the relationships which a man and a woman may have for three generations, upward and downward. In doing this it is desirable to avoid the ambiguous use of English terms, such as cousin, uncle, and aunt, under which a number of different kinds of relationship are confused, even brother and sister being used inexactly to express whole brother and paternal or maternal half-brother, &c. In fact, the published schedules of kinship are imperfect in this respect. It is desirable to interpret each term into its strict meaning, expressed by father and mother, son and daughter, husband and wife; for instance, father's father's daughter, mother's son's wife, &c. This scheme of relationship will often be found to constitute a classificatory system, as mentioned above, and in respect of which it will be necessary to observe the use of the term of relationship rather than the personal name as a form of address, and the distinction between elder and younger brothers, sisters, and other kinsfolk. Customs of avoiding certain relatives, as where the husband affects not to recognise his wife's parents, are of interest as social regulations.

Government and Law.—When it is noticed how the system of chiefship, councils, &c., among the Iroquois, on being carefully examined by visitors who understood their language, proved to be most systematic and elaborate, it becomes likely that the scanty details available as to groups of West Canadian tribes might be vastly increased. Such old accounts as Hearne has left us of the Tinneh or Athapascans (whom he calls Northern Indians), and Carver of the Sioux, are admirable so far as they go; but in reading them it is disappointing to think how much more the writers might have learnt had they thought it worth the trouble or that any readers would care to know it. Even now, though old custom has so much broken down, present and past details of savage political life may be gained among the western tribes on both sides of the Rocky Mountains.

The prominent points are the distinction between the temporary war-chief and the more permanent peace-chief; the mode of succession or election to these and lower offices; the nature of the councils of old men and warriors; personal rights of men and women of different classes; the rules of war and peace; the treatment of captives and slaves; the family jurisdiction, with especial reference to the power possessed by the

father or head of the household and others; the law of vengeance and its restrictions; the tribal jurisdiction in matters, especially criminal, concerning the community; the holding of land and other property by the tribe or family; personal property, and the rules of its distribution and inheritance; the law of hospitality. The observer will in such inquiries frequently come into contact with forms of primitive communism, not only as to food, but as to articles of use or wealth, such as guns and blankets, which are of great interest, as is the custom of obtaining social rank by a man's distributing his accumulated property in presents. All these matters, and far more, are, as a matter of course, known with legal accuracy to every grown-up Indian in any tribe which is living by native rule and custom. In the rapid breaking-up of native society it remains for the anthropologist at least to note the details down before they are forgotten.

Religion and Magic.—The difficulty of getting at native ideas on these matters is far greater than in the rules of public life just spoken of. On the one hand the Indians are ashamed to avow belief in notions despised by the white man, while on the other this belief is still so real that they fear the vengeance of the spirits and the arts of their sorcerers. It is found a successful manner of reaching the theological stratum in the savage mind not to ask uncalled-for questions, but to see religious rites actually performed, and then to ascertain what they mean. The funeral ceremonies afford such opportunities; for instance, the burning of the dead man with his property among Rocky Mountain tribes, and the practice of cutting off a finger-joint as a mourning rite, as compared with the actual sacrifice of slaves for the deceased, as well as the destruction of his goods among the Pacific tribes. Here a whole series of questions is opened up—whether the dead man is considered as still existing as a ghost and coming to the living in dreams, of what use it can be to him to kill slaves or to cut off finger-joints, why his goods should be burnt, and so on. In various parts of America it has long been known that funeral rites were connected with the belief that not only men but animals and inanimate objects, such as axes and kettles, had surviving shadows or spirits, the latter belief being worked out most logically, and applied to funeral sacrifices, by the Algonkins of the Great Lakes. It is probable that some similar train of reasoning underlies the funeral ceremonies of the Rocky Mountain and Columbian tribes, but the necessary inquiries have not been made to ascertain this. More is known of the native ideas as to the abode of the spirits of the departed, which is closely connected with the theory of souls. There is also fairly good information as to the prevalence in this region of the doctrine, only just dying out in the civilised world, of diseases being caused by possession by devils, that is, by the intrusion of spirits into the patient's body, who convulse his limbs, speak wildly by his voice, and otherwise produce his morbid symptoms. Books of travel often describe the proceedings of the sorcerer in exorcising these disease-demons; and what is wanted here is only more explicit information as to the nature of such spirits as conceived in the Indian mind. Even more deficient is information as to how far the ghosts of deceased relatives are regarded as powerful spirits and propitiated in a kind of ancestor-worship, and the world at large is regarded as pervaded by spirits whose favour is to be secured by ceremonies, such as sacred dances, and by sacrifices. The images so common on the Pacific side are well known as to their material forms, but anthropologists have not the information

required as to whether they are receptacles for spirits or deities, or merely symbolical representations. The veneration for certain animals, and prohibition to kill and eat them, partly has to do with direct animal-worship, but is mixed up in a most perplexing way with respect for the totem or tribe-animal. In fact, many travellers, as, for instance, Long the interpreter, already mentioned, have confused the totem-animal with the medicine-animal, which latter is revealed to the hunter in a dream, and the skin or other part of which is afterwards carried about by him as a means of gaining luck and escaping misfortune. Above these lesser spiritual beings greater deities are recognised by most tribes, whether they are visible nature-deities, such as Sun and Moon, Heaven and Earth, or more ideal beings, such as the First Ancestor, or Great Spirit. There is still great scope for improving and adding to the information already on record as to the religious systems of the tribes of the Dominion, and hardly any better mode is available than the collection of legends.

Mythology.—As is well known, most Indian tribes have a set of traditional stories in which are related the creation of the world, the origin of mankind, the discovery of fire, some great catastrophe, especially a great flood, and an infinity of other episodes. Such, for instance, are the legends of Quawteaht, taken down by Sproat among the Ahts, and the Haida stories of the Raven published by Dawson. These stories, written down in the native languages and translated by a skilled interpreter, form valuable anthropological material. It is true that they are tiresome and, to the civilised mind, silly; but they are specimens of native language and thought, containing incidentally the best of information as to native religion, law, and custom, and the very collecting of them gives opportunities of asking questions which draw from the Indian story-teller, in the most natural way, ideas and beliefs which no inquisitorial cross-questioning would induce him to disclose.

In studying the religion and mythology of the various tribes, and also their social constitution, their arts, their amusements, and their mental and moral traits, it is important to observe not only how far these characteristics differ in different tribes, but whether they vary decidedly from one linguistic stock to another. Some observers have been led to form the opinion that the people of each linguistic family had originally their own mythology, differing from all others. Thus the deities of the Algonkins are said to be in general strikingly different from those of the Dakotas. Yet this original unlikeness, it is found, has been in part disguised by the habit of borrowing tenets, legends, and ceremonies from one another. This is a question of much interest. It is desirable to ascertain any facts which will show whether this original difference did or did not exist, and how far the custom of borrowing religious rites, civil institutions, useful arts, fashions of dress, ornaments, and pastimes extends. Thus the noted religious ceremony called the 'sun-dance' prevails among the western Ojibways, Crees, and Dakotas, but is unknown among the eastern tribes of the Algonkin and Dakota stocks. It would seem, therefore, to be probably a rite borrowed by them from some other tribe in the vicinity of those western tribes. The Kootanies of British Columbia, immediately west of these tribes, are said, on good authority, to have practised this rite before their recent conversion by the Roman Catholic missionaries. If it is found, on inquiry, to have prevailed universally among the Kootanies from time

immemorial, the presumption would seem to be that this tribe was the source from which the others borrowed it. Careful inquiry among the natives will frequently elicit information on such points. Thus the Iroquois have many dances which they affirm to be peculiar to their own people. They have also a war-dance which differs in its movements entirely from the former. This dance they declare that they borrowed from the Dakotas, and the statement is confirmed by the name which they give it—the Wasâsé, or Osage dance.

Apart from the mythological legends, the genuine historical traditions of the different tribes should be gathered with care. In obtaining these it must be borne in mind that, commonly, only a few Indians in each tribe are well informed on this subject. These Indians are usually chiefs or councillors or 'medicine men,' who are known for their intelligence, and who are regarded by their tribesmen as the record-keepers of the community. They are well known in this capacity, and should always be consulted. Ordinary Indians are frequently found to know as little about their tribal history as an untaught English farm labourer or French peasant commonly knows of the history of his own country. This fact will account for the mistake made by some travellers who have reported that the Indians have no historical traditions of any value. More careful inquiry has shown that the Iroquois, the Delawares, the Creeks, and other tribes had distinct traditions, going back for several centuries. These are often preserved in chants, of which the successive portions or staves are sometimes recalled to mind by mnemonic aids, as among the Delawares (or Lenâpé) by painted sticks, and among the Iroquois by strings of wampum. The Creeks and the Dakotas kept their records by means of rude pictographs painted on buffalo skins. Such records should be sought with care, and the chants should be taken down, if possible, in the original, with literal translations and all the explanations which the natives can give. Colonel Mallery's memoir on 'Pictographs of the North American Indians,' in the Fourth Annual Report of the United States Bureau of Ethnology, and Dr. Brinton's volume on 'The Lenâpé and their Legends,' might be referred to as aids in this inquiry. It would be very desirable that the music of these chants should be taken down by a competent musician.

Conclusion.—In this brief series of suggestions some published works relating to the Canadian Indians have happened to be mentioned, but many more have been left unnamed. These, however, are not left unnoticed, but every available publication is now consulted for anthropological purposes, and those who collect information in reply to the present circular may feel assured that all evidence contributed by them will be duly recognised in the study of savage and barbaric culture, which furnishes data so important for the understanding of the higher civilised life.

The Rev. E. F. Wilson has furnished the Committee with the following report of his proceedings:—

Report on the Blackfoot Tribes. Drawn up by the Rev. Edward F. Wilson, and supplementary to that furnished in 1885 *by Mr. Horatio Hale.*

Before proceeding with my report I would like just to say, by way of explanation, that I have been working nineteen years among the Ojibway Indians of Ontario as a missionary, have two institutions for Indian

children at Sault Ste. Marie, and during the last three summers (since the C. P. Railway was opened) have been visiting the Cree, Saulteaux, Sioux, and other tribes in Manitoba and the North-West, in the hope of inducing those Indians to send some of their children to our institution. Last summer six Sioux boys and six Ojibway boys from the north-west came to us, and this summer I have succeeded in bringing down two young Blackfeet from their prairie home at the foot of the Rockies. We have in our homes at present 52 Indian boys and 27 Indian girls. Mr. Hale, hearing of my projected visit to the Blackfeet Indians, asked me to act in his place in furnishing the following report; and, as I am quite unused to this sort of undertaking, I hope that any blunders I may make in my style of writing or in the putting together of the material which came into my hands will kindly be overlooked. I think I may vouch for it that whatever I have offered in the following pages is the result either of what I have seen with my own eyes or have gained from the lips of reliable Indians or from missionaries living on the spot.

The Blackfoot Indians, as Mr. Hale mentioned in his report of 1885, consist of three tribes, united in one confederacy, speaking the same language, and numbering in all about 6,000 souls. The common name by which they call themselves is Sokitapi, the prairie people. Siksikaw, Blackfeet, is a title given to the northern tribe by those living in the south (*i.e.* the Bloods and Péigans) on account of the black earth, which soils their feet; where the Bloods and Péigans live (50 miles or so to the south) the land is gravelly or sandy, so that their feet are not made black. The Bloods call themselves Káinaw (meaning unknown). The Péigans call themselves Pekániu (meaning unknown). By the white people they are all called, in a careless way, Blackfeet.

Whence they Came.

Chief Crowfoot (Sapomakseka), the head chief of the whole confederacy, with whom I had a long and interesting interview, was very positive in asserting that his people for generations past had always lived in the same part of the country that they now inhabit. He entirely scouted the idea that they had come from the East, even though I cautiously omitted any reference to the theory that the Crees had driven them. 'I know,' he said, 'the character of the soil in all parts of this country. The soil of Manitoba I know is black, but that proves nothing, for this soil where we are now living is black also, and hence our friends to the south call us Blackfeet: our true name is "Sokitapi," the prairie people.' In answer to further inquiries, Chief Crowfoot said that there were no people west of the Rockies in any way related to them. His people crossed the mountains sometimes to trade with the British Columbia Indians, but their language was quite different, and they were entire strangers to them. He informed me, however, that there were a people a long way to the south in the United States who were related to them, and spoke the same language as they did. One of his wives, he said, came from that tribe. The woman was present in the teepee, and he pointed her out and ordered her to tell me what she knew. I questioned and cross-questioned the woman closely, the Rev. J. W. Sims, who has been four years among the Blackfeet, and is well acquainted with their language, interpreting for me. The information I drew from the old woman appeared to me most interesting. She said it was a journey of about thirty days' distance, and,

by putting together certain names which she mentioned and the character of the country as she described it, we found that the tribe to which she alluded lived in New Mexico or Arizona, and were in close contiguity to the domains of the curious Moqui Indians, who build their houses on the cliff tops. The name of the tribe she said was 'Nitsipoie,' and they were near to a people called Moqui-itapi (the Moqui people). It may possibly be from this quarter that the Blackfeet derive their worship of the sun. While travelling among them I saw very few people, whether men or women, who had not suffered the loss of one or more fingers (some as many as four) cut off at the first joint, the severed member having been offered to the sun. The second chief under Crowfoot is named Natúsi-apiw (old sun), and these people during my short visit (six days) did me the honour of adopting me into their nation and giving me the name Natúsi-ásamiu, which means 'the sun looks upon him.'

I thought it might further help to decide whence these Blackfeet originally came if I asked what other hostile tribes they had fought with. These are the names of the tribes:—The Kòstenai, or River Indians; the Flatheads; the Kouminétapi, or Blue Indians; the Matuyókawai, or grasshouse Indians; the Aksémini Awáksetcikin, or gum getters (said to rub gum on the bottom of their feet instead of wearing moccasins); the Apăksinamai, or flat bows; the Pitséksinàitapi, or Snake Indians; the Piétapi, or strangers; the Atokipiskaw, or long earring Indians; the Istsitokitàpi, or people in the centre; the Awáksaawiyo, or gum eaters. All these they say either live or used to live in and about the Rocky Mountains. Their enemies have also been the Sioux, Crows, Crees, and Nez Perces.

The fact that these people neither build boats nor canoes, nor eat fish, seems to me another proof that they have not come from the Lake region to the east.

Some of their Traditions.

Chief 'Big Plume,' another minor chief in the Blackfoot camp, gave me the following information. I have put it down word for word as it was interpreted to me:—

How Horses originated.—A long time ago there were no horses. There were only dogs. They used only stone for their arrows. They were fighting with people in the Rocky Mountains. Those people were Snake Indians. They took a Blackfoot woman away south. There were a great number of people down there, and they tied the woman's feet, and tied her hands behind her, and a cord round her waist, and picketed her to a stake near the big salt water. And they cried across the lake, 'See, here is your wife!' Then they all retreated and left her. These big lake people did not see her at all; but the waters rose and covered her; and when the waters abated, there was no woman there, but there were lots of horses. The Snake Indians caught these horses, and that is how horses began.

The Creation.—It had been long time night. Napi the Ancient said, 'Let it be day,' and it became day. Napi made the sun, and told it to travel from east to west. Every night it sinks into the earth, and it comes out of the earth again the next morning. Napi is very old every winter, but he becomes young every spring. He has travelled all along the Rocky Mountains, and there are various marks on the mountains which remain as relics of his presence. Napi said, 'We will be two

people.' He took out the lower rib from his right side, and he said, 'It shall be a woman,' and he let it go, and he looked on it, and he saw a woman. He then took a rib from the left side, and said, 'Let it be a boy,' and it was a boy. Napi also made a number of men with earth. Napi and the men went one way, the woman went another way. And the woman made women of earth in the same way as Napi had made men.

At Morley, opposite the Rev. John Macdougall's house, and down the river, said Big Plume, there is a little stream; they call it the men's kraäl or enclosure; on one side of the stream is a cut bank and big stones; this was the men's boundary, beyond which they were not to pass. They used to hunt buffalo, and drive them over the cut bank; they had plenty of meat; they had no need to follow the buffaloes; they hid themselves behind the big stones and uttered a low cry; this guided the buffalo to the cut bank, and when they were over the bank they shot them with their stone arrows and ate the meat.

One day Napi went out on a long journey. He got as far as High River. There he saw lots of women together, with the woman made from his rib, who acted as their chief. There were no men and no boys there. There were a great number of teepees. Napi was alone. He told the women, 'I have come from the men.' The woman chief said to him, 'Go home; bring all your men; stand them all on the top of this stone ridge; our women shall then go up one by one, and each take a man for a husband.' When they were all up there, the chief woman went up first and laid hold on Napi to take him, but Napi drew back; the chief woman had put on an old and torn blanket, and had rubbed all the paint off her face, and had no ornaments on her. Napi did not like her appearance, and so he rejected her addresses. He did not know that she was the chief woman. She then went back to the women, and, pointing to Napi, said, 'Don't any of you take him.' She then dressed herself in her best, and painted her face, and put on her ornaments, and went and chose another man. All the women did the same. Thus all the men had wives, and Napi was left standing alone. The chief woman then cried aloud, 'Let him stand there alone like a pine tree.' Napi then began breaking away the stony ridge with his heel, till there was only very little of it left. The woman then shouted, 'Be a pine tree.' And the pine tree stands there now alongside the big stones, and they still call it the women's kraäl. Napi's flesh is in the pine tree, but his spirit still wanders through the earth.

The boy made from Napi's left rib fell sick. The woman took a stone and threw it in the water, and she said, 'If the stone swims the boy will live,' but the stone sank and the boy died; and so all people die now. If the stone had floated, all people would have lived.

First Appearance of the White Man.—The Sai-u (Sioux?) were the first to see the white men. The Crees first brought the news to the Blackfeet. That was the first time they saw axes and knives and tobacco. The Crees said they heard guns firing. The white men were shooting buffaloes with guns. The white men took them to their teepees, and showed them their guns and knives. The white men came from the far east. They call white men 'Nápi-ăkun,' but cannot tell whether this has any reference to Napi the Ancient.

Eclipse of the Sun.—They say that the sun dies, and that it indicates that some great chief has either just died or is just going to die.

How their Arts originated.—Napi gave them the first specimens of

every article they use, and they make the copies. They never try to make new things, unless instructed to do so in a dream. Nevertheless, they make no difficulty about using things made by white people.

Religion.

These people, notwithstanding that missionaries of the Roman Catholic Church, the Church of England, and the Methodist Communions have been working among them for several years past, are still, nearly all of them, with scarcely an exception, heathen. They seem to be more than any other north-western tribe opposed to adopting either the customs or religion of the white man. Their own system of religion has been already well explained by Mr. Hale, but I may perhaps add a few additional items of interest which I have gathered. The following is from the lips of 'Big Plume':—

'Young men go up on to a hill, and cry and pray for some animal or bird to come to them. Before starting out they wash themselves all over and put off all their clothing and ornaments except a blanket. For five or six days they neither eat nor drink, and they become thin. They take a pipe with them and tinder and flint, and a native weed or bark for smoking (not matches or tobacco). When the pipe is filled they point the stem to the sun and say, "Pity me, that some animal or bird may come to me!" Then they address the trees, the grass, the water, and the stones in the same manner. If anyone crosses their path while so engaged, they call aloud to them to warn them off, saying, "I am living alone. Do not come near!" While in this state they dream, and whatever animal or bird they see in their dream becomes their medicine or guardian through life. They are told also in a dream what description of herbs or roots to gather as their medicine, and this they collect and put carefully into a small bag to keep as a charm. They also kill the animal that they dreamed of, and keep its skin as a charm. No one knows what is the medicine they have gathered; it is kept a profound secret. The little bag is kept in the tent, and no one may touch it but the owner. Other Indians would be afraid to meddle with it. There is no particular age for young men to engage in the above rites. They start away in the evening—only in summer. Some go of their own accord, others are bid to do so by their fathers or elder brothers. If they do not go, any sickness that comes upon them will certainly be fatal, or if shot by an enemy they will certainly die.'

I asked 'Big Plume' what did he think became of the soul after death? He replied that the souls of all Blackfeet Indians go to the sandhills north of the cypress hills (this would be to the east of the Blackfeet country). What proof had he of that? I asked. 'At a distance,' said the chief, 'we can see them hunting buffalo, and we can hear them talking and praying and inviting one another to their feasts. In the summer we often go there, and we see the trails of the spirits and the places where they have been camping. I have been there myself, and have seen them and heard them beating their drums. We can see them in the distance, but when we get near to them they vanish. I cannot say whether or not they see the Great Spirit. I believe they will live for ever. All the Blackfeet believe this; also the Sarcees, Stonies, Atsinàs, and Crees. The Crees after death will go to the sandhills farther north. There will still be fighting between the Crees and the Blackfeet in the spiritual world. Dogs

and horses go to the sandhills too; also the spirits of the dead buffaloes. We hand these traditions down to our children. We point out to our children various places where Napi slept, or walked, or hunted, and thus our children's minds become impressed.'

From inquiries I have made I am able to corroborate all that Mr. Hale has said in regard to the sun-dance and the amputation of their fingers and offering them as a sacrifice to the sun. Both these customs, on account of the cruelties accompanying them, are now discountenanced by the Canadian Government, and are likely before long to fall into disuse.

Government &c.

The head chief of the Blackfeet is Sapomákseka (Crowfoot). Under him are 'Old Sun,' chief of the Northern Blackfeet; 'Red Crow,' chief of the Bloods; 'North Axe,' chief of the Péigans. Over the southern Blackfeet, Crowfoot is himself the chief. There are also three or four sub-chiefs belonging to each tribe. The position is not hereditary, but, it would seem, is assumed by the man who possesses the most talent, tact, and power in the tribe. At present the chiefs are paid a small annual pittance by Government, 5*l.* to each principal chief, and 3*l.* each to the minor chiefs. The power of a chief is not defined; he is in fact a czar, possessing an absolute control over his camp. He has a number of young men employed as soldiers to execute his commands. If the order is given to move camp or to come to a sun-dance and any disobey, the soldiers go round and violently strip the covering from the teepee, tear it to pieces, scatter the contents to the winds, and sometimes kill the dogs.

Tomahawks are not much used by the Blackfeet Indians. Their weapons are a bow and arrows, a war club, a scalping-knife, and, for defence, a circular skin shield ornamented with feathers. Many of them have also guns or rifles. They will not fight openly, and are regarded by other tribes as cowardly. Their tactics are to avoid the enemies' missiles by jumping from side to side, and they have a hole in the shield through which they look and try to deceive the enemy by putting the shield to one side of their persons, as a mark to aim at, instead of in front. They always scalp their foes when fallen.

I cannot discover that there are any clans or gentes existing among these people, but they have various orders connected with their dances, and those who belong to the order have to imitate the bird or animal whose name they have adopted as their totem. Young unmarried men wear a badge of beadwork and hair on each shoulder to show that they are available for marriage.

Food.

The principal and almost only food of these people was formerly buffalo meat. A man would eat on an average about eight lbs. a day. White people who have lived on it say that there is something very appetising about buffalo meat, and that it is no hardship to eat it alone without bread or vegetables. It is very different, they say, to eating beef. The Blackfeet Indians have never grown any corn, and never knew what bread was until the white man came among them. When in camp it was usually their practice to boil the meat, but when out on a hunting expedition, without any cooking utensils, they would put the flesh on spits before a large fire and roast it. It used to be a common practice to make

youths who had not yet been on the warpath hold the meat while roasting, so as to harden them to endure suffering. The Indians never used salt before the white man came, but are now very fond of it. They seem to like strong-tasting food, and sometimes make a mixture of strong black tea, tobacco, and 'pain-killer,' which they drink with great relish. The Blackfeet seldom, if ever, eat fish; I am told that they regard it as unclean. They preserve berries by drying them in the sun. Principal among these are the Saskatoon berry and the choke cherry. The latter they pound up when newly picked, and spread it on sheets of parchment to dry; then they powder it up and put it in skin bags. It is called by white people 'choke cherry pemmican,' and is said to be very palatable. These people, in common with other nomad Indians, usually eat two meals a day—breakfast and supper. The latter, however, is often prolonged to an indefinite period after a successful day's hunt. When they get up in the morning the first thing they do is to wash. The Blackfeet Indians are very particular about this, even in the depth of winter. For soap they use ashes from the fire, and they usually rinse out their mouths thoroughly with water. It is a common practice to take a deep draught of cold water on first awakening in the morning. Directly after breakfast the usual thing is either to move camp or to start on a hunting expedition. The little fetish, or charm, shaped out of stone like some animal or bird, and wrapped round with roots, herbs, clay, and beads, is placed on end the night before, and in whichever direction it has fallen that is the direction in which to look for the buffalo. The hunt occupies the day, and in the evening, when work is over, they will eat a heavy and long-continued meal. For the above information I am indebted principally to the Rev. John Macdougall, of the Methodist Missionary Society, who has for many years past been labouring among these and neighbouring tribes of Indians. Now that the buffaloes are all gone, these people would be forced to starve were it not for the Government rations which they receive. Each individual receives one pound of good beef and half a pound of flour per diem. The buffalo disappeared in 1879–80. Before that time they might be counted by thousands. Their sudden disappearance has never yet been satisfactorily accounted for. None now remain in Canada, and only very few are to be found in the United States.

Medicine.

I had no opportunity of talking to the Blackfeet Indians themselves about this, and had I done so they would probably have been unwilling to reveal their secrets. I however gathered from Mr. Macdougall the names of some of their most frequently used medicines. (1) *Minweg* (Cree), a vegetable; little short sticks; a strong, pleasant aromatic flavour, like celery; used for headache, catarrh; also for smoking. (2) *Bear root*; tastes like liquorice; used for colic. (3) *Rat food*; a flag root, with a sharp, pungent taste; they grind it up and drink it like hot tea; used for various diseases. *Bleeding* is done with a piece of sharp flint fastened into a stick like a veterinary surgeon's fleam. They bind the arm till the vein is swollen, put the edge of the flint on the vein, and strike it with a stick. *Cupping* is done by scarifying the part with a flint or pricking it with needles and then drawing the blood to the surface by sucking through a horn. *Amputation* of a limb is never resorted to, but they will patch up a bad wound, and often succeed in effecting a cure where an English surgeon would have amputated. These

things are not done by the professional 'medicine men,' but by any man or woman in the camp who is clever enough. The 'medicine men' resort only to witchcraft in attempting their cures.

Dwellings, Occupations, &c.

While sitting in 'Old Sun's' teepee I mentally took its dimensions and noted down its contents. It was about sixteen feet in diameter on the floor and about eighteen feet high in the centre, formed by fifteen poles, their feet on the line of the circle and their upper ends meeting in a bunch at the top, the framework covered over with white tent canvas, yellowed and browned with the smoke. In the centre was a circlet of smooth stones, two and a half feet in diameter, forming the fireplace, and over the fire was a tin pot, suspended by three sticks—gipsy fashion. Overhead hung some pieces of dried beef on a string. The interior of the teepee, unlike those of the Crees and Sioux, was divided into four partitions by sloping back-resters, called 'stopistákiská,' and made of wickerwork; their basis, about twenty inches wide, rested on the ground, and their tops, which tapered to three or four inches in breadth, were secured to the sloping poles which supported the tent about four feet from the ground. The teepee also had its sides lined with quilts and blankets to a height of four feet from the ground, which gave it a warm, comfortable appearance. Back in the angle made by the sloping sides of the tent were packed away all the valuables which the family possessed—blankets, packsaddles, guns, &c.—and on the front of these partitions, towards the fire, a neat finish was made to each couch by a clean-shaved pole lying on the ground. The teepee had no floor, only the grass of the prairie, but the couches between the partitions were carpeted with skins and blankets. All the feather ornaments, headdresses, shields, buckskin dresses, &c., were neatly folded up and packed away in skin cases made to contain them. There was an air of neatness and cleanliness about the whole arrangement. 'Old Sun' exhibited to us some of his valuables. There was a circular shield, twenty inches in diameter, made of skin stretched over a wooden frame and ornamented with red cloth and crimson-dyed feathers. On the face of the shield was a rude picture of a buffalo and some marks like this  which we were told represented the buffalo trail. We were also shown a skin helmet, mounted at the top with a buffalo horn studded with brass nails. The helmet was one mass of weasel tails, hanging in every direction, and the point of the horn, which pointed backwards and downwards, had a tuft of crimson feathers. There was also a very elaborate headgear for a horse to wear when going to battle. One part of it covered the head like a mask, holes being left for the eyes, and was fitted with a pair of horns; the other part was a sort of banner, to be suspended to the lower jaw; both parts were profusely decorated with red, yellow, and blue feathers. We were told that such a headdress as this was, in Indian estimation, worth a couple of ponies.

These Blackfeet seem to live in teepees such as I have described in the summer, but in the winter it is now their custom to dwell in little log huts plastered over with mud, which they have learnt to construct, in imitation, it is thought, of the lumberer's shanty. It seems to me, however, after seeing models of the Moqui and Pueblo Indians' houses at the Smithsonian Institute, that it is quite as likely that they had this style

of dwelling previous to the coming of the white man. I enclose a sketch of both the exterior and interior of one of these mud huts. The sides are made of logs, plastered over with mud; the roof is almost flat, made of poles, covered first with prairie grass and then earth. There is always a fireplace, not built into the wall, but standing a little way from it. It is just a long, mud, rudely constructed chimney, reaching from a foot above the roof down to the ground inside the hut, a little widened at the base, and an arched opening in front for the fire. Sometimes the hut has a little square hole for a window, but more often the only aperture is the doorway. The floor is partly covered with poles, flattened on the upper surface. A few sticks stuck into or between the logs serve for pegs. The occupants of two or three teepees usually unite for the winter, and occupy one mud hut between them. The hut would not be more than twelve by eighteen feet in size.

Clothing and Ornaments.

A man's dress consists of a breech cloth; a pair of leggings made of coloured blanket or cloth, with a fringe of long loose strips down the outer side of each leg; a pair of buckskin moccasins ornamented with beads; and over his shoulders a white, scarlet, or parti-coloured blanket. This is his whole dress. He wears no hat. His blanket is wrapped round his shoulders, or up around his head, or slipped down to his waist—according to the temperature of the weather or the whim of the moment. His neck is encircled by several necklaces, made of twisted brass wire, large bright-coloured beads, bones of a deer's tail, the small bones of a deer's foot, or the claws of a bear. He has earrings, made of brass, wire, beads, or shell (brought from the Pacific coast). Generally he wears a coil or so of brazen rings on his fingers. Sometimes his wrists or arms are tattooed, but not often. Usually his face is painted either with crimson or ochre. He does not wear feathers in the head as a general thing. These are kept rather for special occasions. His hair is allowed to grow long and is plaited; usually a plait on each side of the face, hanging vertically, and one or two more plaits at the back; the hair is sometimes twisted into a knot at the point known as the scalp-lock. A man has the greatest objection to his hair being cut short; he wears it, it would seem, in defiance of his enemies, and boasts that none shall cut it off while he is alive. The dress of the woman resembles that of her European sister, but is very roughly constructed and shorter in the skirt. She has no under garments, but wears leggings like the men and a blanket over her dress. Her neck, arms, fingers, and ears are profusely ornamented with brass, bead, and bone rings. Little children under four years of age sometimes have nothing on but a little apology for a shirt, reaching barely to the waist, but their little arms and necks are loaded with ornaments and charms. There is never any indecent exposure on the part of either sex. They are always particularly careful about this. The women, however, make no attempt to hide their breasts when suckling their infants.

The Blackfeet women do not use board cradles for their babes like the Ojibways. Board cradles are seldom seen west of Lake Superior. The Blackfeet babes are wrapped up warmly and laced into a bag, which the mother carries on her back.

A chief's dress sometimes has marked on it a record of his exploits. Chief Crowfoot bade us count the black lines on his buckskin rope—they amounted to 143—and he said that he had been in 143 fights.

Manufactures.

The Blackfeet have the name of being a lazy people, and, beyond making the ornaments which adorn their persons and the saddles for their ponies, they certainly do not seem to do much in the way of manufacture. They make no boats or canoes, no baskets, no articles of metal. The most that they attempt to do in this line is to fashion a few rude wooden bowls and platters, and horn spoons, and plaited ropes.

Marriage.

The Blackfeet are polygamous, some of the men having as many as ten wives. Girls mature early, and become wives as early as at twelve years of age, and are sometimes mothers at fourteen. The families average five or six children. The women are strong, and undergo but little inconvenience in bringing their children into the world. Mr. Macdougall has known a woman when travelling to go aside from the trail, and in little more than an hour to be on her pony again with an infant in her arms. There is no marriage ceremony; so many ponies or other presents are given by the intending husband to the parents of the bride, and then he takes her away.

Games and Amusements.

The Blackfeet have no regular ball game. They sometimes engage in feats of strength, wrestling, and foot-racing, but their chief amusements are horse-racing and gambling. For the latter of these they employ dice of their own construction—little cubes of wood, with signs instead of numbers marked upon them—these they shake together in a wooden dish. Holding some small article in the hand under a blanket, and rapidly passing it from one hand to another, leaving the second party to guess in which hand it is left, is another method. They have also a little wheel made of metal, covered over with cloth, three or four inches in diameter, which they roll towards two arrows stuck in the ground, and see towards which it will fall the nearest. There is always heavy betting on a horse race; each chooses his favourite, and then they begin throwing down in a heap the articles they wish to stake—blankets, guns, lines (representing ponies), tents, &c. Those who win take the whole heap, and divide it among themselves; even their wives are sometimes gambled away in this manner.

Burial of the Dead.

The Blackfeet never bury their dead below the surface of the soil; they think it a horrible practice to expose the body to the worms and vermin that live in the ground. They either deposit the bodies on a hill-top or place them in a tree. Perhaps, being sun-worshippers, their idea is that the sun should still shine upon them after they are dead. When the body is placed in a tree it is wrapped in blankets and put up on a rudely constructed platform. When deposited on a hill-top or cliff a rough kind of box is made, three times the size of a coffin, and into it are put, besides the body, all that belonged to the dead person—blankets, saddle, gun, kettles, and everything; it is then nailed down, dragged by a pony on a travoiè to the appointed spot, and there deposited. Sometimes a few logs are piled round it to keep off the dogs and wild animals, but often

nothing is to be seen but the rudely made box and some kind of a flag flying above it. When a chief dies his favourite pony is brought and killed at the door of his tent; his body is then laid out in his own teepee, often in a sitting position, and all his possessions are spread around him; the edges of the tent are wedged down and secured with stones, then the teepee is closed and left. This is called a 'death teepee.' Travellers sometimes come across a solitary teepee with no signs of life around it, and on looking in are horrified to see a decomposing corpse. There is great grief when a person dies. The people weep and howl over the dead bodies of their friends. It is usual also for the friends to throw their blankets and other valuables into the coffin before it is closed. A mother has been known to wrap her last remaining blanket around her dead infant, even in the middle of winter. Mr. Tims told me of a father walking several miles barefoot through the snow to bury his little child, having given his moccasins to the dead infant. The graves of the dead are visited by the living; the people often come and hold a feast with the departed spirits, setting aside portions of food for them. The Blackfeet seem to have no dread of ghosts or spirits, and do not mind handling dead bodies. It is not an unusual thing for a 'death teepee' even to be rifled by those bent on plunder.

Physical Development.

I picked out, as nearly as I could, an average Blackfoot Indian—his name was Boy Chief, aged 44 or 45—and measured him from head to foot, the result being as follows:—

		ft.	in.
1.	Height from ground to vertex	5	$8\frac{3}{4}$
2.	" " meatus auditorius	5	$2\frac{7}{8}$
3.	" " chin	4	$11\frac{1}{2}$
4.	" " top of sternum	4	$7\frac{1}{2}$
11.	" " elbow (bent)	3	$5\frac{1}{2}$
5.	" " umbilicus	3	$4\frac{5}{8}$
7.	" " fork	2	$7\frac{3}{8}$
12.	" " tip of finger (hanging vertically)	2	$2\frac{3}{8}$
8.	" " knee-cap joint	1	$7\frac{5}{8}$
16.	Circumference of chest at armpit	2	$11\frac{1}{8}$
	" " mammæ	2	$9\frac{1}{2}$
18.	" at haunches	2	$8\frac{1}{2}$
26.	Span—outstretched arms	5	11
27.	" thumb to middle finger	0	$8\frac{1}{8}$
28.	Length of thumb	0	$2\frac{5}{8}$
	" foot	0	$10\frac{1}{8}$
13.	Height– sitting on the ground	2	10
30.	Head—greatest circumference (over glabella)	1	$10\frac{1}{2}$
41.	" length of face, root of nose to chin	0	$4\frac{5}{8}$
32.	" arc meatus audit. over head to chin	1	$2\frac{1}{2}$
31.	" " root of nose to inion	1	2
33.	" " over glabella	1	$0\frac{1}{2}$

The hair of the Indians is black, straight, somewhat fine, and abundant in quantity; it grows to about 3 feet in length, and is put up in large plaits, one on each side of the face, and generally one or more at the back. There is no hair on the face; if any grows it is very little. The few stray hairs that appear are plucked out with small iron tweezers. The colour of the skin, not exposed to the air, is No. 21 (two other persons agreed with me on this point), and of the eye, No. 1 towards the centre, and No. 16 towards edge of iris.

Intellectual Capacity.

As no children of this tribe have, as yet, been induced to remain even for a few consecutive weeks at school, it is impossible to report at present on this head. I have, however, succeeded in inducing two boys to return with me to our Shingwauk Home (1,500 miles distant from their reserve), and it will be very interesting to see in the course of a year what progress they make, in comparison with boys from other tribes. The Blackfeet have all the appearance of being an intelligent people; and I saw two boys at the mission who were evidently beginning to understand intelligently the use of the letters of the alphabet, for they had several times suggested to Mr. Tims alterations in his mode of spelling Blackfoot words; one of them, I found, had in his possession a list of Blackfoot and English words, evidently trying to teach himself the English language. Like all other Indian tribes, they learn very quickly to write a good hand, and many of the children show a taste for drawing.

The Language.

I entirely endorse Mr. Hale's view that the Blackfeet language is a branch of the *Algonkin stock*, having a near affinity to that spoken by the Ojibways and Crees; the grammatical construction is almost precisely the same, and a good many of the words are similar. The Sioux language, spoken by some 2,000 Indians in the North-West Territory, is an entirely distinct language, both in structure and vocabulary, but the other languages south of the Saskatchewan Valley, viz. Cree, Blackfoot, Saulteaux, and Ojibway, are clearly all of one common stock. Following are a few words in the three principal tongues which bear some resemblance to one another:—

	Ojibway	Cree	Blackfoot
Man	inini	iyiniw	nin'nau
woman	ikwe	iskwew	akew
name	ijinikásowin	ijihikásowin	inikásim
my daughter	nidánis	nitánis	nitána
wood *or* tree	mitik	mistik	mistis
I	nistoa, -ni	niya, -ni	nin, -ni
thou	kistoa, -ki	kiya, -ki	kin, -ki
yes	A	A	A
my leg	nikad	niskat	nokatsi
kettle	akik	askik	iska

But it is in the grammatical construction of the three languages that the resemblance is the most marked. I shall notice eleven points in order:—

1. *The distinction between animate and inanimate plurals.*

In Ojibway animate nouns make their plurals in	*g, ig, og*;	inanimate in	*an, un.*
In Cree " "	*ok, ak*	"	*a*
In Blackfoot " "	*ax, ix, ox*;	"	in *esto, isto.*

In all three languages an animate noun must be followed by an animate verb, and *vice versâ*.

2. In all three languages a distinction is observed between the *first person plural* exclusive and the first person plural inclusive. Thus:—

	Ojibway	Cree	Blackfoot
Our house (excl.)	niwigiwáminan	niwaskáhiganinan	nokoanan
" (incl.)	kiwigiwáminan	kiwaskáhiganinau	kokoanan

3. *Distinct endings to express the second third person and the third third person in a sentence.*—This rule is peculiar to Ojibway and Cree, but I could not ascertain whether or not the Blackfeet observe the same distinction.

4. *The adjective is placed before the noun* in these three languages. In some other Indian languages, *e.g.* Sioux, it follows the noun.

5. *All adjectives* (with the exception of adjectival particles used only as prefixes) *can be transformed*, with but very little alteration, into impersonal verbs; thus (Blackfoot) *agsi*, good; *agsiu*, it is good. This is similar to Ojibway and Cree.

6. *Personal and possessive pronouns.*—The first and second persons, singular and plural, as shown in Mr. Hale's report, have the same first syllable and nearly the same plural endings in all three languages, viz. *ni*, I, my; *ki*, thou, thy. Plural endings—*nan*, we, our; *wa*, *waw*, you, your.

7. *The objective case of the pronoun* is in all three languages embodied in the verb. Thus:—

	Ojibway	Cree	Blackfoot
I love thee	kisagiin	kisakihitin	kităkomimo
thou lovest me	kisagi	kisakihin	kităkomimok
thou lovest us	kisagiimin	kisakihinan	kităkomimokipinan
he loves us	nisagiigonan	nisakihikonan	nităkomimokinau

8. *The simplest form* (and often the root) of the verb is the singular imperative. Thus:—

	Ojibway	Cree	Blackfoot
Sleep thou	nibán	nipá	okát
give it to him	mij	miy	kúkit

9. *The negative is double*, as in the French language:—Ojibway, *kawin . . . si*; Blackfoot, *mat . . . at* or *ats*. In Cree they have only the simple word *namáwiya* or *nama* before the verb. Thus: I do not love him. Ojibway, *kawin nisagiasi*; Cree, *namáwiya nisakihew*; Blackfoot, *ni-mat-takomimau-ats*.

10. *There is a distinct form for the negative imperative.* Ojibway, *kego . . . ken*; Cree, *ekawiya* or *eka*; Blackfoot, *mini* or *pini*. Thus: Do not give it. Ojibway, *kego mina ken*; Cree, *ekawiya miy*; Blackfoot, *mini kukit*.

11. *An interrogative particle* is used in all three languages. Ojibway, *ina*; Cree, *tci*; Blackfoot, *kat . . . pa*. Thus: Are you happy? Ojibway, *kiwawijendam ina?* Cree, *kimiyawatam tci?* Blackfoot, *kikateagsitakipa?*

There may very likely be other analogies between these three languages, but the above are as many as I have had time to inquire into.

There are two sounds in the language which are difficult of pronunciation, and students are undecided as to how best to write them.

(*a*) There is a sound between *kr* and *ks*. I suggest writing it *kc*, thus: *nikcista*, my mother.

(*b*) There is a sound between *ch* and *ts*. I suggest writing this *tc*, thus: *tcema?* Where?

In the following vocabulary the letters and sounds are pronounced as follows: *a* as in father, *ă* as in bat, *e* as in they, *i* as in pique, *ĭ* as in pick, *o* as in note, *u* as *oo* in cool, *ai* as in aisle, *au* as *ow* in cow, *iu* as *ew* in few, *j* as *z* in azure, *g* like *ch* in the German.

Vocabulary of Blackfoot words.

man	nin'nau
woman	akéw
boy	sag'komápi
girl	akékoăn
infant	s'itsiman
my father	nin'nă
my mother	nikcistă
my husband	nó'mă
my wife	notokéman
my son	nokó-a
my daughter	nităn'na
my elder brother	nì-ĭs
my younger brother	niskăn
my elder sister	nin'stă
my younger sister	nitakīm
Indian	niitci-tapīwa
people	matápiwa
head	mótokan
hair	mokóiekinsin
face	mostóksis
forehead	monīis
ear	mogtókis
eye	moŏpspi
nose	mòksisis
mouth	mah'ŏi
tongue	màtsini
teeth	mogpekists
beard	imoyòwăsin
neck	mòkokin
arm	mots'ĭmĭn
hand	motcĭs
fingers	mokitsĭix
thumb	omăkokitsis
nails	owot'ănokitsix
body	mostom
chest	mokīkin
belly	mókoan
female breast	ún'nikis
leg	mo'katsi
foot	mòăpisak
toes	mokitsiix
bone	ogkĭn
heart	moskitsipap
blood	áapăn
town	ákapioyis
chief	nin'nau
warrior	soòyiepitsi
my friend	nipīă
house	nápioyis
skin loage	moyīs
kettle	iska
bow	náma
arrow	ăpsi
axe	koksáki
knife	īstóan
boat	àkiosàtsis
moccasins	'atsikists
pipe	akwīniman
tobacco	pista'kăn
sky	nàmotàk
sun	natùsi

moon	kókumikèsum (night-light
star	kákătosi
day	kc'istikui
night	kokúyi
morning	kciskănátăni
evening	o'tăkuyi
spring	motúye
summer	nepúye
autumn	mokúye
winter	stuyé
wind	sopúyi
thunder	kcistcikúm
lightning	aipopúm
rain	so'taiyi
snow	kùn'skwii
fire	istcī
water	ogké
ice	kokutúyi
earth	kcăkum
sea	istcíksipokogké
river	niyétagtai
lake	omáksikimi
valley	isteīkúm
prairie	sau-ké
mountain	netúm'mo
island	mini
stone	'okotóki
salt	istcíksipoko
iron	mikskim
forest	as'oaskwi
tree	mistcis
wood	mistcis
leaf	suyópokist
bark	otokis
grass	matuyis
pine	pagtogki
flesh	ikcisàko
dog	ĭmita
buffalo	enĭwă
bear	kiàiyo
wolf	apīsi
fox	otátuye
deer	'owătúye
elk	ponokà
beaver	kcistagki
rabbit	'atcista
horse	ponokámita
fly	sosksìsi
snake	pitsèksina
bird	pīksi
egg	owăw
feather	măm'in
goose	'apspini
duck	sa-ái
fish	măm'mī
name	nimikasim
white	ksiksinăm
black	siksinăm
red	máksinăm
blue	kùmuninàtsi

yellow	otokúinăm	nine	pīkso
green	otskúinăm	ten	kèpo
big	omăkimi	eleven	kepo nitcikóputo
small	enăkimi	twelve	kepo nàtcikóputo
strong	skúnitapi	twenty	nàtcippo
old	nápi	thirty	nìippo
young, new	máni	ninety	pīksippo
good	agsi	one hundred	kepìppo
bad	pakáppi	one thousand	omăksi-kepippo
dead	eniu	he eats	aú-yi-u
alive	sàkiaitàpi	I eat	nit-au-yi
cold	stúye	he drinks	àisimiu
this	'amu	I drink	nītàisimi
that	'omăk	he runs	aukskásiu
all	konai	he dances	aiàipiu
many	àkaiim	he sings	ninikiu
who	taká	he sleeps	ai-ókau
far off	piétsi	he speaks	epúyiu
near	astótsim	he sees	'ăsăpiu
here	anùm	he sees him	nanuyéwaie
there	omīm	he kills him	īnìtsiu-ai-e
to-day	anòk kcistcikui	he loves him	ăkomimiu-ai-e
yesterday	mătăn'ni	he sits	itaúpiu
to-morrow	ăpinákwis	sit down	'apiit
yes	a	he stands	itàipuyiu
no	sa	he goes	ităppo
one	nitùkskăm	I go	nitai-ităppo
two	nàtokăm	go	tappót
three	niókiskăm	he comes	púksipu
four	nisoyím	come	puksipút
five	nìsitci	he walks	ăwăwăkau
six	n'ăwyi	he works	ăpotăkiu
seven	ikìtsikăm	he steals	àikomosiu
eight	nániso		

Notes by Mr. H. Hale on the Report of the Rev. E. F. Wilson.

Mr. Wilson having submitted to me his valuable report, I add a few notes, comprising some facts which have come to my knowledge since my report of 1885 was prepared.

In that report I suggested that the non-Algonkin element of the Blackfoot language, as well as their peculiar religious ceremony, the 'sun-dance' (which is not found among the eastern Algonkins), might have been derived from some tribe west of the Rocky Mountains. The natives of that region who are nearest to the Blackfeet are the Kootenais, a people in some respects of noteworthy and superior character.

Father De Smet, in his 'Indian Sketches,' describes them as 'the best disposed of all the mountain Indians.' They are highly esteemed among the traders for their good qualities, and particularly for their scrupulous honesty. With this people the Blackfeet have had close relations, in peace and war, from time immemorial. My intelligent correspondent, Mr. J. W. Schultz, an educated gentleman, who has resided for several years among or near the American Blackfeet, and has written much about their usages and traditions, informs me that the Kootenais, before their recent conversion by the Roman Catholic missionaries, practised the sun-dance. This he had learnt from Indians of that tribe. He adds: 'In old times, however, the Kootenais lived as much on this side of the mountains as they did on the other.' This accords with other information which I have received to the same effect. As the Blackfeet

now occupy the country which the Kootenais formerly possessed, on the east side of the mountains, it is clear that the Blackfeet must have expelled the Kootenais from that country, and very probably have conquered and absorbed some portion of the tribe. It is to this quarter, therefore, that we should naturally look for the strange element in the Blackfoot language. We find, accordingly, that the word for 'sun,' which in the Blackfoot language is totally different from the corresponding word in all other Algonkin tongues, bears an evident resemblance to the Kootenai name of that luminary. In Blackfoot the word is *natos* or *natusi*; in Kootenai it is *natanik.* The words differ merely in their terminations. There can hardly be a doubt that, when the Blackfeet borrowed from their former neighbours their most peculiar and remarkable religious ceremony, they borrowed also the name of the sun-deity to whose worship it was devoted.

Two of the legends given by Mr. Wilson deserve notice in this connection. He was informed that the Snake Indians first had horses, and that these came out of the 'big salt water' which has tides. This event is combined with another—that of the carrying away of a Blackfoot woman to the south by 'the snakes.' The snakes are the Shoshonees. This widespread people, whose bands wandered over a vast region, from California to Texas, were in former days among the most inveterate enemies of the Blackfeet. To the tradition related by Mr. Wilson some facts may be added from the statements of Mr. Schultz. He mentions that horses were first known to the Blackfeet about the beginning of the present century, and that 'they were stolen from the south.' Putting all these circumstances together, we are warranted in concluding that the Blackfeet first obtained horses by capturing them from the Shoshonees in a war which was kept in memory not only by this event, but also by the fact that a Blackfoot woman was made prisoner and carried off by the enemy. From the prisoners whom they made in turn the Blackfeet learnt that the strange animals which they had taken came from the great salt water. Horses were probably first known to the Shoshonees in California, where they were introduced by the Spaniards in the latter part of the last century. The Shoshonees would learn from the Spaniards that the horses had come originally across the ocean. This information passing from tribe to tribe over the continent reached the Blackfeet in the shape of the myth which Mr. Wilson has obtained. What is chiefly to be noted is that this myth, which by its form might be thousands of years old, has yet unquestionably originated within less than a century.

This modern shaping of the Blackfoot mythological stories is also apparent in the account of the making of the first woman and man from the ribs of Napi. This portion of the creation myth, which does not appear in the version furnished to me by Father Lacombe, is evidently a novel feature, derived very recently from the missionary teachings.

We are now prepared to find an event of not very ancient history involved, as may reasonably be conjectured, in the remarkable tradition obtained by Mr. Wilson concerning the women who lived by themselves in a district adjoining the land of the Blackfeet, and who finally took husbands from among the latter. This story holds apparently an important place among the Blackfoot legends. A correspondent, who has paid much attention to such subjects—Mr. George Bird Grinnell, Ph.D., of New York (editor of 'Forest and Stream')—sends it to me as he learnt it from his Blackfoot (Péigan) guide during a hunting tour in the Far

West two years ago. In this form the story does not appear to have anything directly to do with the creation. It becomes one of the many tales in which the 'Old Man' (Napi) is represented as playing the fool, and as tricked by other powers or by mortals. In reference to his name, which Mr. Wilson and others write *Napi*, and Father Lacombe *Napiw*, and which Mr. Grinnell renders 'Old Man,' it may be mentioned that *Napi* is an adjective, signifying 'old.' Used as a name, it might be rendered 'The Old One' (in French, *Le Vieux*; in German, *Der Alte*). *Napiw* is a verbal form, used also as a name, and signifying, properly, 'He who is old.' The following is the legend as told to Mr. Grinnell :—

'As Old Man was going along he came to a big lodge, which was the woman's home. He went in. The women said to him, "Do you think that you have men for husbands for us?" He said, "Who is chief here?" A woman replied, "That woman behind is chief." He said to the chief woman, "To-morrow let those women come to the valley. A Péigan will be there, finely dressed, with leggings trimmed with weasel-skin; very handsome is his wearing apparel." The chief woman replied, "Let the others wait. I am first chief woman; I will be the first to take a husband." Now Old Man wanted very much to have the chief woman for his wife, although she did not look nicely. She had been making dried meat, and her hands and arms and clothing were covered with blood and grease. The next day the chief woman came to the valley, and there she found many men. In the midst of them was Old Man, splendidly dressed, with weasel-skin leggings. As soon as she saw him the chief woman recognised Old Man; so she let them all go, and went back to the women. To them she said, "You can take any of these men except the finely dressed man who stands in the middle. Do not take him, for he is mine." Then she put on her best apparel, and went to the valley. The women went to look for husbands. Old Man [who wished to be chosen by the chief woman] stayed far behind [so that he should not be taken by any of the others]. All the women chose husbands, and took all the men to their lodges. One man was still left unchosen—it was Old Man. The chief woman said, "Old Man thought I was a fool. Now we will make a buffalo piskan [enclosure], and I will change him into a pine log, and we will use him for a part of the fence. So Old Man is the fool, and not the woman."'

As we know the legend of the origin of horses had a recent historical foundation, so we may also conclude that this story of the women and their choice of husbands, coupled with the rejection of Napi, had its origin in some actual occurrence of perhaps no very remote date. We know, from other noted traditions—such as the 'Rape of the Sabines' and the capture of wives for the children of Benjamin—how such marriages by wholesale, as they might be styled, are likely to take place. If there ever was a camp of Indian women with whom no men were found, we may be tolerably sure that they were the survivors of a war in which all the fighting men of their tribe had been slain. The band of Kootenais, who formerly dwelt east of the Rocky Mountains, was certainly not dislodged by their Blackfeet enemies without a desperate war, in which, as a natural and almost inevitable result, the men would be killed—perhaps in a fight at a distance from their homes—and the women, who were left at home, would be afterwards made prisoners, and would become the wives of the conquerors. Such events are of common occurrence in Indian history. The liberty given to the captive women, when once received as

members of the Blackfoot nation, of choosing their own husbands would be entirely in accordance with Indian sentiments and habits. That these women should despise and reject Napi, the peculiar and rather ridiculous divinity of the Algonkins, and should introduce the worship of their own glorious sun-god, is intelligible enough. Thus we can see how a tradition as improbable on its face as the coming of horses out of the salt water may represent an actual event which has deeply affected the language, religion, and character of the Blackfoot nation. A similar occurrence, described in Müller's 'Grundriss der Sprachwissenschaft,' had a still more remarkable consequence. The Caribs (Galibis) of the South American mainland, having conquered the Arowaks, who inhabited the neighbouring islands, put the men to death and took the women for wives. The women, with true Indian independence, retained their own language among themselves, and taught it, as well as the language of their husbands, to their children. The result was that two languages were subsequently spoken in the tribe—the Galibi among the men, and the Arowak (mixed, however, with some Carib elements) among the women. If the conquest had taken place a few generations earlier the two languages would doubtless have been by this time fused into one—a Carib speech, with many Arowak elements—and the origin of the mixed race would have become a story of the Carib mythology.

I may venture to add that Mr. Wilson's carefulness in preserving these native stories—however trivial they might at first seem—precisely as they were received by him deserves particular acknowledgment.

The Committee ask for reappointment, with a renewal of the grant.

Second Report of the Committee, consisting of Dr. GARSON, Mr. PENGELLY, Mr. F. W. RUDLER, *and* Mr. G. W. BLOXAM (*Secretary*), *appointed for the purpose of investigating the Prehistoric Race in the Greek Islands.*

THE Committee have to report that they have again had the benefit of Mr. and Mrs. Bent's valuable assistance in carrying on investigations during the past year. The results of explorations must always be uncertain from the fact that when an exploration is begun, however promising it may seem to be, it is impossible to tell whether expectations will be realised regarding it. This year, however, the explorations which Mr. Bent undertook for the Committee have proved to be successful, as they have resulted in the discovery of an ancient temple, which proved to be of Apollo, containing no less than thirteen ancient inscriptions which have been successfully photographed by Mrs. Bent. The structure and plan of the temple have been thoroughly explored, and a marble statue, unfortunately wanting the head, but nevertheless of considerable value, has been found. Several of the tombs adjoining the temple have been explored, and massive and elaborate sarcophagi of considerable interest found in them, which illustrate the customs and art of the inhabitants of these islands in ancient times.

The field selected for exploration has been an extremely interesting one, and the work which has been done has thrown much light on the ancient marble commerce of Thasos.

As the Committee attach considerable value to the report which was presented to it by Mr. Bent of the work done by him, it has been thought advisable to incorporate that report in the present report of the Committee to the Association.

The sum of 20*l.*, placed at the Committee's disposal by the Association last year, has been entirely expended on wages to the workmen engaged in excavation.

The Committee have much pleasure in tendering its best thanks to Mr. and Mrs. Bent for the indefatigable zeal with which they have conducted the researches, attended as they have been with no small personal inconvenience arising from imperfect accommodation obtainable at the scene of their labours, and expenses not defrayed by the grant of the Association.

The Committee ask to be reappointed, and that a similar sum be placed at their disposal. They recommend that Mr. Bent's name be also added to those forming the present Committee.

Report of Mr. Bent to the Committee.

The Ancient Marble Commerce of Thasos.

Last winter, with the grant from the British Association, I was enabled to make excavations and close examinations at one of the chief centres of marble merchandise of the ancient world. The quarries of Thasos were chiefly productive of what we may term a fashionable marble during the epoch of Hadrian and the decadence of Hellenic art, but long before the time of its popularity Thasiote marble was in use for domestic purposes when Parian and Pentelic were exclusively used for statuary; and having visited these three great quarries of white marble, I am inclined to think that from Thasos during the course of ages far more has been taken than from the other two.

Herodotus tells us that a statuary marble was in the first instance discovered here by the Phœnicians; whilst Pliny tells us that it was less livid than the Lesbian, and on examination we found the texture of the Thasiote marble decidedly compact, and the grain formed of bright and medium-sized scales, and very subject to rot when exposed to water. From Seneca we further gather that in his time 'fish preserves were made of Thasiote marble,' and at this period it was considered a marble of inferior quality, for Papinio Stagio, in describing the magnificence of an edifice, adds that Thasiote marble had not been admitted in its construction. Pausanias, on the other hand, assures us that the late Athenians held it in great estimation, and had two statues in honour of Hadrian made of it, which were placed in the temple of Olympian Zeus at Athens. The Euripides in the Vatican is made of it, and Belloni asserts that the exterior of the pyramid of Caius Sestius in Rome was coated with this marble. This is about all that is known of the quarries until the investigations we made into the subject during our stay in Thasos last winter.

Owing to the position of the quarries they were very easily worked, and the marble was most handy for exportation. A promontory consisting wholly of marble juts out into the sea on the southern coast-line of Thasos; it is about a mile in length, and rises in parts to about 300 feet above the sea-level. This promontory at its extreme point has been completely cut down to the sea-level, forming a large flat surface over which the sea dashes in storms, and in the hot weather the inhabitants of a village

some four hours distant come here to collect the salt which forms in the crevices out of which the marble blocks have been cut. From this fact the locality has acquired the modern name of Alki, a name common enough in spots where salt marshes exist.

This flat nose of the marble promontory forms an interesting study of the methods adopted for quarrying marble in ancient times. Here we see the shape and size of each block as it was cut—some square, some rounded, and all cut away round the edges, and holes bored in regular lines underneath, a means adopted for raising the block that they wished to detach. Most of the loose blocks which have remained here unexported since ancient times have been removed for building purposes to Constantinople in late years, but the old inhabitants informed me that thirty years ago this flat space was covered with such blocks. We saw a few of them, and also the drum of a column 6 ft. 8 in. in diameter, and 4 ft. 4 in. high, and a monolithic column 30 ft. long and 3 ft. 8 in. in diameter. On the higher ground deep quarries are to be seen, and on the isthmus which joins the promontory to the mainland are the remains of a considerable town of ancient date, where doubtless the workmen and marble merchants had their dwellings. Here it was that we commenced the excavation of the temple which proved to be of Apollo; but before describing our work and its results in detail I will say a few words about a road of excellent Hellenic engineering which was constructed across the mountains and connected this marble town with the ancient capital of Thasos, some six hours distant.

Traces of this road in an excellent state of preservation are found at intervals all along the ancient line of route, but owing to the burning of an extensive tract of forest a quarter of an hour's walk from Alki a short time ago a portion in the bend of a hill has been exposed to view, which is almost as perfect as when originally in use. It is constructed of irregular blocks of marble placed lengthwise, so that the whole width of the road is only composed of two blocks, and is a uniform width of 13 ft. 3 in. Wherever it was possible the engineer utilised the neighbouring marble rocks in constructing his road; it is noticeable that at the angles of the valley, where mountain streams run down, there is no conduit for water beneath, and the stream must have made its way across the roadway itself; but so massive are the blocks that not one of them has been displaced by the action of the water. At intervals along the road there are towers for protection, several of them well preserved, and taken as a whole it forms one of the most interesting specimens of ancient engineering skill that has come down to us.

After carefully inspecting Alki we determined on commencing our excavations at a spot down by the water's edge, where some huge marble blocks in tiers indicated the existence of a building of considerable importance on the top of the platform. The lower tier of steps came down almost to the water's edge, or rather down to a curious concrete quay, which in ancient times ran all round the marble promontory, and must at least have been three miles in extent, projecting some twenty feet into the water, and then ending abruptly, for the water here as elsewhere amongst the islands has risen several inches.

There were five tiers or steps, composed of some of the largest marble blocks I have ever seen. The one at the northern angle of the lowest grade measured 16 ft. 11 in., was 5 ft. 3 in. wide and 2 ft. 4 in. thick; whereas the block at the northern angle of the top tier was 12 ft. long.

The building, which originally stood on the top of this massive platform, was of the Doric order, and consisted of two chambers, the *débris* of which and the foundations were hidden by several feet of soil, in which fir trees of considerable age were growing.

The long side of the platform facing the sea measured 54 ft., and 2 ft. 4 in. from the outer edge we came across the outer wall of the temple, offering a façade to the sea of 45 ft. 9 in. in length. Until we had proceeded some way with the excavation we found few traces on this side, which, from its proximity to the sea, had doubtless been robbed of its principal features at an earlier date. At the south-western corner of this outer chamber, which was in width 32 ft. 7 in., we came across a raised platform, on which originally stood an archaic statue of Apollo; along this, in letters of an early period, ran the inscription ΔΑΟΣ ΑΠΟΛΛ, which I take to be a rare dedication either to the 'wolf god' Apollo or in connection with the sun god (*δάος*, a torch, a light).

At a little distance from this platform we came across the marble trunk of an archaic statue, broken off below the knees, and without a head, and measuring from the neck to below the knee 4 ft. 5 in. Around the shoulders it was 4 ft. $10\frac{1}{2}$ in., and round the waist only 3 ft. 4 in.; it had down the back 15 braids of hair, and, at the top of each, holes in which ornaments had been fixed. Strength was curiously developed in the chest and sinews, and the idea of the knee was given by a curious trefoil-like excrescence.

In front of this platform we came across a number of large marble slabs, with votive inscriptions from mariners, thanking the gods for a successful voyage. The most interesting was dedicated to 'Sminthean Apollo, who gives good voyages,' and relates how the offerer had sailed around 'the misty island' (*ἀερίην νῆσον*). This is a curious allusion to the old legendary name of Thasos, *Ἀερία*, or the misty island, which was given to it in this wise. An early band of colonists, in the ninth century B.C., from the other marble island of Paros, sought from the Delphic oracle directions as to where they should go. 'Go to the misty island' was the reply; and Thasos, according to their idea, being the most misty place they knew, they repaired thither, colonised it, and called it *Ἀερία*.

Another votive tablet of later date was dedicated to Artemis, 'who gives good voyages,' by Eutychus, the captain, Tychichus, the mate, and Jucundus, the helmsman, of a ship. Amongst this interesting *débris* of an ancient cult, we likewise found a small archaic head, of exceedingly rude workmanship, and a curious, well-cut stone, 3 ft. 1 in. by 1 ft. 3 in. thick, down the front edge of which was carved a curious head, as of Poseidon, with a long beard in five braids, which seemed as if it had been one of two sides to a seat.

The wall which divided this outer chamber from an inner one was built of huge blocks of marble, fastened together with iron rivets, set in lead, only the foundations being in their place; the first and second blocks of this wall, measuring 3 ft. 2 in. and 12 ft. $2\frac{1}{2}$ in. respectively, formed the base of a neatly cut square pattern which had adorned this portion of the wall; then came the door, the hinge-holes of which were still distinguishable, measuring 5 ft.; close up against the southern side of the entrance stood a large block of marble, with an inscription on it relating the names of various archons, polemarchs, apologoi, a local Thasiote name for the logistai, or auditors of accounts, and the name of a sacred herald. Close to this stood a pedestal, without inscription, and which doubtless

carried a small statue, of which no fragments were found; but about three feet from the wall we laid bare a larger pedestal, with votive inscriptions behind and before. The inscription to the front was headed with the name of Athene, and went on to thank Hercules, 'who gives good voyages.' The inscription behind purported to be the εἰσφορός, a curious form of the word εἰσφορά, giving, I suppose, the idea of tribute to some god whose name was unfortunately obliterated. Near this pedestal we found fragments of a draped statue, which had presumably stood upon it. Also an archaic circular pedestal with Doric flutings, 6 ft. 2 in. round at the base, 1 ft. 6 in. in diameter at the top, 3 ft. 2 in. round the neck, and standing 3 ft. 5 in. high. This pedestal is similar to several which have been found amongst the archaic remains on the Acropolis at Athens.

Along the southern wall of this chamber ran another raised platform, similar, though slightly lower, to the one on which the statue of Apollo had stood in the other chamber. On this we found a small votive altar, with an inscription stating that it had been put up to Dionysos, the oppressor of wrath (μῆνι τυράννῳ), and in the wall behind was a stone bearing the inscription, in letters of a good period, 'the Dionysian herald of love.'

This chamber was considerably smaller than the other, measuring only 14 ft. 8 in. across; it had been paved with marble, but the outer wall towards the town showed signs of considerable alterations in the original scheme during the Roman period; however, on the central slabs of this frontage wall, we found the bases of two Doric columns, 2 ft. 8 in. in diameter, with 22 flutings and 6 ft. 6 in. apart. This platform was 3 ft. 1 in. wide, and between and around the pillars were many names and sentences scribbled, also phallic designs. One of the names, in large and good letters, was Aristogeiton, and another recorded the name of 'Simos the gay, the good at heart.'

But at the southern side this wider platform and the Doric columns had been replaced by a narrower platform, with traces on it of a later colonnade, and before it stood the circular bases of two columns of a debased period; and from fragments we found it would appear that badly executed Ionic columns had been erected at the time of these later alterations, and stood side by side with the massive Doric columns of the earlier scheme.

Between the southern wall of the temple and the hill which rose abruptly behind it ran a narrow passage, with steps leading down to the sea. The wall on the hill-side, evidently erected as a facing to the natural rock, was composed of blocks of marble of extraordinary thinness in comparison to their length, the first that we uncovered being 11 ft. 5 in. long, 1 ft. 7 in. high, and only 7 in. thick. This passage was 7 ft. 4 in. wide, and at forty feet from the top of the steps was divided by a wall and a door. Time did not permit of our following this passage up further, but it evidently was in connection with the temple, for on one stone of the outer wall of the temple we found a much obliterated inscription, of which all we could decipher was 'to Poseidon, who gives good voyages,' and in another line the name Asclepius, and in a third the name Pegasos. Also we found another well-cut stone with *Anteros* scribbled on it in large irregular letters (Anteros, the revenger of unrequited love).

These are the principal features of the temple which we excavated,

and, from the thirteen inscriptions which we found amongst its ruins, it would appear that in the first instance it was dedicated to Apollo, doubtless from the fact that the early colonists, in search of marble, considered that they had been guided thither by the Delphic response; and the rude headless trunk which we found was presumably the first representation of their god, which they erected for worship; but in later ages this temple would appear to have been converted into a perfect pantheon, where the sailors and merchants who carried the Thasiote marble into distant lands set up their votive tablets and brought their offerings.

Beside the temple we made some slight excavations amongst the tombs of this marble town, which were of exceedingly elaborate workmanship, but of the same style that we had seen in other parts of this island. Massive marble sarcophagi, averaging about 8 ft. long by 3 ft. wide, and 4 ft. deep, made out of single blocks of marble, and covered with a marble lid, pointed in the centre like a roof, and with four large bosses at each of the corners. We found many of these buried in the sand by the shore at the neck of the isthmus, where it joins the land. All of them had been opened in ancient times, no doubt to extract the objects of gold which the Thasiotes invariably put in their tombs. Objects in terra cotta are curiously rare in Thasos, most likely owing to the fact that the Thasiotes owned the extensive gold mines on Mount Pangæus, on the mainland opposite, and considered it right to put objects of this precious metal in their tombs. Occasionally unopened tombs are found, and confirm this statement; notably, the so-called tomb of Antiphon, in which a marble figure was found wearing a tunic of gold, but unfortunately a Bulgarian workman who had been employed in opening the tomb managed to steal it, and nothing more has been heard of it.

On one of the lids of a sarcophagus at Alki we found that the bosses had each been decorated with a female head; another had its bosses decorated with wreaths of flowers, and the sloping roofs were occasionally decorated with diaper patterns. Long metrical inscriptions seem to have been much in vogue for these tombs. One stands in the centre of the town, with an inscription twelve lines in length. We found many fragments of metrical inscriptions, and the tomb which the family of Asclepiades had put up to one of their members; also an inscription telling us that in the tomb was buried 'the slave of the four,' *Θρεωιος τῶν τεσσάρων*, concerning which I am not prepared to offer an explanation.

There are many interesting spots in the immediate neighbourhood of Alki which we were able to visit on Sundays and feast days, when our workmen did not come. All these spots are connected with the marble enterprise. About two miles to the west of Alki is the bay of Temonia, on the west side of which are high cliffs of marble, rising straight out of the sea like a wall some 200 to 300 feet in height. All this has been cut away by the marble quarrying, and there are evident signs of the blocks having been let down by pulleys into the ships, which could anchor close to, in the deep water beneath. There are ruined houses about here in many points, and at the top of a rounded hill in the centre of the bay is a round Hellenic tower of excellent workmanship; this tower is 49 ft. 9 in. in diameter in the interior, the wall being 3 ft. 4 in. thick; it is built in courses of marble, exceedingly regular, the joints being all vertical, and the length of the blocks composing it varies from 3 ft. 6 in. to 2 ft. The entrance to this tower is on the eastern side; it is low, and with a pointed arch formed by the stones of the courses overhanging each other, and re-

calling the entrances of many archaic buildings in Greece. On one of the blocks near this door I read the word Αρτεμι, being an abbreviated form of Αρτεμιδι, which we had found on one of the votive tablets in the temple at Alki. The interior of the tower is almost entirely choked up with fallen blocks from the surrounding wall, and the *débris* of later habitations, but it seemed to me that a thorough excavation of this tower might produce some valuable results respecting ancient systems of fortification.

Between this bay of Temonia and Alki there is another well-preserved rectangular Hellenic tower and the ruins of another village. So we find, within a very short distance, no less than two villages and one town, all well protected, and all in former ages thriving on the quarrying and export of marble, connected with an admirable road to one of the great centres of Hellenic culture and progress, and affording us a highly interesting study of a commercial centre, dating from centuries before the Christian era, and bearing traces of having continued in prosperity down well into the period of the Eastern Empire.

Report of the Committee, consisting of Professor G. CAREY FOSTER, Sir WILLIAM THOMSON, Professor AYRTON, Professor J. PERRY, Professor W. G. ADAMS, Lord RAYLEIGH, Dr. O. J. LODGE, Dr. JOHN HOPKINSON, Dr. A. MUIRHEAD, Mr. W. H. PREECE, Mr. HERBERT TAYLOR, Professor EVERETT, Professor SCHUSTER, Dr. J. A. FLEMING, Professor G. F. FITZGERALD, Mr. R. T. GLAZEBROOK (*Secretary*), Professor CHRYSTAL, Mr. H. TOMLINSON, Professor W. GARNETT, Professor J. J. THOMSON, Mr. W. N. SHAW, *and* Mr. J. T. BOTTOMLEY, *appointed for the purpose of constructing and issuing Practical Standards for use in Electrical Measurements.*

THE Committee report that the work of testing resistance coils has been continued at the Cavendish Laboratory, and a table of the values found for the various coils is given.

Legal Ohms.

No. of Coil		Resistance in Legal Ohms	Temperature
Elliott, 183	No. 173	·99938	16·3°
Elliott, 184	No. 174	·99924	16·3°
L. Clark & Muirhead, 251 .	No. 175	10·0040	17°
Elliott, 117	No. 63	·99976	15·9°
Elliott, 185	No. 176	·99962	15·8°
Elliott, 186	No. 177	·99959	15·8°

B.A. Units.

No. of Coil		Resistance in B.A. Units	Temperature
Elliott, 41	No. 55	1·00286	16·2°
Elliott, 56	No. 56	1·00039	16°
Univ. Coll. coil . . .	No. 63	·99983	16·2°
Taylor's coil . . .	No. 68	·99985	18·25°
Taylor's coil . . .	No. 69	10·00209	18·1°
Price coil	No. 66	1·00289	19·2°
Price coil	No. 67	1001·39	19·4°
Warden, 292 . . .	No. 70	9·99416	16·5°

Of these the coils Elliott Nos. 41, 56, and 117 have been tested before, but owing to the green coloration mentioned in the last report showing itself in the paraffin, the paraffin was removed and the coils refilled with ozokerit, which can be obtained more nearly free from traces of acid.

This change in all cases produced an appreciable increase in resistance, amounting in the case of Elliott No. 41 to about ·0025.

The coils 63, 68, and 69 are three of the original B.A. units.

70 is a coil sent over from the Johns Hopkins University for the purpose of connecting their value of the B.A. unit with that found at the Cavendish Laboratory.

Shortly after the Birmingham meeting of the Association the Secretary received a letter from the Board of Trade enclosing a copy of the general bases of a convention proposed by the French Government for the consideration of the Powers, with the object of carrying out the resolutions of the Paris Congress with regard to electrical standards.

The convention stipulates that a legal character is to be given to (1) the legal ohm; (2) the ampère; (3) the volt; (4) the coulomb; (5) the farad.

It charges the Bureau International des Poids et Mesures, established by the Metric Commission, with the construction and conservation of the international prototypes of the standard of electrical resistance, the comparison and verification of national standards and secondary standards.

These questions had, at the request of some of the English delegates to the Congress of 1883, been considered by the Committee at the Birmingham meeting, and the following series of resolutions, which the Secretary was instructed to forward to the British Government, had been agreed to on the motion of Sir William Thomson, seconded by Professor W. G. Adams :—

(1) To adopt for a term of ten years the legal ohm of the Paris Congress as a legalised standard sufficiently near to the absolute ohm for commercial purposes.

(2) That at the end of the ten years period the legal ohm should be defined to a closer approximation to the absolute ohm.

(3) That the resolutions of the Paris Congress with respect to the ampère, the volt, the coulomb, and the farad be adopted.

(4) That the resistance standards belonging to the Committee of the British Association on electrical standards now deposited at the Cavendish Laboratory at Cambridge be accepted as the English legal standards conformable to the adopted definition of the Paris Congress.

In reply, therefore, to the letter of the Board of Trade, the Secretary forwarded a copy of the above resolutions, with a statement of some of the reasons which had led to their adoption by the Committee.

During the year the original standards of the Association have again been compared by the Secretary. An account of this comparison and of the very complete one made in the years 1879–80–81 by Dr. Fleming, the details of which have not been published previously, will be given shortly.

At the last meeting of the Committee it was resolved, on the motion of Mr. W. H. Preece, seconded by Sir William Thomson, to recommend the adoption of the Watt as the unit of power.

The Watt is defined to be the work done per second by the ampère passing between two points between which the difference of electrical potential is one volt.

The Committee were also of opinion that it is highly desirable to proceed with the construction of an air condenser as a standard of capacity, and for this purpose they desire to be reappointed, with the addition of the name of Mr. Thomas Gray and a grant of 100*l.*

Supplement to a Report on Optical Theories. *By* R. T. GLAZEBROOK, *M.A., F.R.S.*

IN my Report on Optical Theories ('B. A. Report,' 1885) I gave an account of Dr. Voigt's Theory of Optics. A recent communication of his to Wiedemann's 'Annalen' shows me that in one point I have unintentionally misrepresented his views.

As I understood his previous papers, the quantities represented by A, B, C (Wied. 'Ann.' xix. p. 874; 'Report,' p. 231), &c., are intended to express completely, so far as the problem before us is concerned, the action of the matter on the ether in the element of volume considered, and that in all cases, even when one face of the element is on the surface.

I took the statement (p. 876) 'indem man die Wirkungssphäre der Molecularkräfte gegen die Grösse des betrachteten Volumen Elementes so klein annimmt dass man die Wirkung die der Aether in demselben erfährt als nur von der Materie desselben Elementes herrührend betrachten kann,' which is precise and definite, as true always, and supposed that the forces acting on the element were known up to the boundary. This being the case, the surface conditions are $X+A=X'+A'$, and not those implied in Kirchhoff's principle. Professor Voigt has explained that this was not his meaning. When one face of the element is on the surface, the forces acting are no longer known. The force denoted by A is to be taken as made up of two—A_{nj} and A_{kh} in his notation—of which A_{kh} arises from the action of the matter in the second medium, and all that is known is that neither loss nor gain of energy is caused by such forces. This, it is

true, is implied in the original paper, and I regret that I misunderstood the statement there.

In consequence of these unknown forces the equations of stress are of no use to us, and we are compelled to have recourse to Kirchhoff's principle to arrive at the conditions. But this appears to me to affect in a fundamental manner the whole of the theory. It ceases in consequence to be a strict mechanical theory of light, for we are ignorant of what goes on in the immediate neighbourhood of the boundary. There is a thin film throughout which our equations of motion do not hold, for throughout it the unknown forces A_{hk}, &c., act. Unless we can show that this film is infinitely thin compared with the wave-length of light, we have no right to assume that the displacements up to the boundary surface are given by the expressions which hold in the interior of the medium.

The actual displacements are, of course, continuous across the boundary, but these displacements will, in addition to what we may term the light motion, involve terms arising from the forces A_{kh}, and such are neglected in Professor Voigt's theory.

With regard to the electro-magnetic theory of dispersion developed by Willard Gibbs, it should be remarked that H' ('Report,' p. 256, 20) vanishes when ξ', η', ζ', the components of the irregular part of the motion, vanish. Now this irregular part of the motion may be supposed to be due to the presence of the matter-molecules, and will therefore disappear in a vacuum; so that in that case we should have H' zero, and there would be no dispersion.

First Report of the Committee, consisting of Mr. R. ETHERIDGE, Dr. H. WOODWARD, *and* Mr. A. BELL, *for the purpose of reporting upon the 'Manure' Gravels of Wexford.*

THE area of the later Tertiary deposit of co. Wexford is described by the late Sir Henry (formerly Captain) James as extending from Arklow to Kilmore in a north to south direction, and inland to Ferns Gorey and Enniscorthy. The very short memoir upon this district ('Journ. Dubl. Geol. Soc.' vol. iii.) was accompanied by a list of the fossils obtained; but the localities from which they were collected not being stated, and the differences in the nature and age of the various sands, gravels, and loamy clays comprehended under the heading 'Post-Tertiary Deposits,' being considerable, it is less useful than it might have been made.

In Professor E. Forbes's well-known memoirs, the fossils are simply recorded as from Wexford or Ireland, Post-Tertiary geology being then in its infancy. These, with a few spare references in papers contributed to the 'Geological Magazine' by Messrs. Harkness, Kinahan, Hull, and the writer, in the 6-in. survey maps, and in two volumes—one on the 'Physical Geology, &c., of Ireland,' by Professor Hull, the Director of the Survey, and the other on the 'Geology of Ireland,' by Mr. G. H. Kinahan, comprise the bibliography of the subject.

The so-called *manure gravels* consist of fine clean sharp sands without stones or organic remains passing up into finely comminuted shell sand, and this, as the fragments become larger, forms a fine gravel containing

shells occasionally perfect,[1] but usually much waterworn and broken, continuing upwards into seams of sand and large gravel, both devoid of life-remains.

The lower sands are well exposed in the cliffs on the north side of the Slaney river, where they repose directly upon the Cambro-Silurian altered rocks. They may be traced northwards to Castlebridge, where they pass up into the higher members of the series at Pulregan, and again seven miles off, near Castle Ellis, the very scanty shelly gravels occurring only at considerable elevations on the *inland* or right flanks of the elevations bordering the coast. A little beyond Arklow the highest gravel only is present, near the coast, this being the northern limits of the series.

Returning to Wexford, one notes the same order of stratification on the right flank of the elevated mass of altered rocks rising behind Wexford. At Rathaspick, the most southerly point to which the writer has traced the gravels, only the uppermost gravel is present; but higher up the road, about two miles off, in Little Clonard, on the same side of the ridge, the upper and shelly portions of the series are well exposed in some sandpits looking towards the Forth Mountain. Here the top gravel is interspersed with thick beds of sand, much thicker than at Pulregan, eight miles away, but is equally wanting in fossils. From Little Clonard the slope descends rapidly for a distance of three-quarters of a mile, and then rises as sharply to the summit of the Forth Mountain, passing over boggy upland and clay, derived from the decomposed subsoil, or schists and quartz gravel.

Three miles north and east, descending towards the river Slaney, the sands, with traces of comminuted shelly sands, appear behind Wexford town, and complete the outline.

From these observations it would appear that the sands and associated shelly gravels are the remnants of a once widespread series, occupying a channel entering somewhere to the south-west of Wexford, having for its right shore the ridges and hills extending from the coast behind Wexford, thence north-by-east to the shore at Arklow.

The deposit of which these are the scanty remains was accumulated before the river Slaney had broken through the Cambro-Silurian schists near Fitzstephen's Castle, since it has cut its way through the lower sands forming part of its banks.

Sir H. James says that a boulder deposit overlies both the Wexford and Wicklow drift, and Professor Hull intimates that the Wexford gravels are without doubt of Middle Glacial age, the faunas being the same and covered by a similar drift.

The writer traverses both these statements. Clay with included rocks abounds, and may be seen in process of formation, rain and heat alike contributing to the disintegration of the original bed rock, the altered Cambrian decomposing rapidly. Unlike the gravel or drift covering the Middle Glacial, the gravels above the shelly part of the Wexford manure gravel are purely local and bear no marks of ice action, and it is very

[1] The term 'manure' applies more especially to this portion, the shelly gravel being spread over lands for the lime contained in them. Shell-bearing loams, and loams containing lime derived from the disintegration of Carboniferous limestone are also used for this purpose, the usual test of its presence being effervescence when treated with oil of vitriol.

questionable if this part of Ireland has ever been subjected to glacial action as generally understood.

The southern side of Wexford Harbour and Wexford Hill, Rosslare Bay, and the adjacent coast cliffs are composed of an earthy loam, which in places contains marine shells. At Ballygeary, near the summit of the cliffs, seventy feet elevation, and in the railway cutting, they may be obtained not infrequently, a thin bed of shingle, extending either side of Rosslare Pier, having yielded about thirty species, these being of a different type from the Wexford gravels, and perhaps representing the sandy beds from which Captain James obtained littoral shells.

This earthy loam is separated by a bed of sand, more or less persistent, one to three feet thick, almost unfossiliferous, one specimen only being obtained from an almost unfossiliferous dense black clay, with very rarely an exotic pebble. An hour's search procured only two fragments of *Pectunculus* and *Astarte.* This clay is derived almost entirely from the calp or black limestone, which is now being worked at Drinagh for cement, a rolled fossil Productus, &c., being occasionally present, and reposes directly upon the palæozoic schists and felsites.

Professor Hull having asserted the identity of the faunas of the Wexford gravels and those of the Middle Glacial deposits, a careful examination was made of the typical section at Ballybraek, in Killiney Bay, on several occasions, and the species then obtained, together with those recorded by other authors and collectors, have raised the known fauna to about forty-five species. Unfortunately the non-localisation of the fossils given by Captain James and the probability that both the Wexford gravels and the cliffs at Ballygeary and elsewhere are included by him render comparison uncertain. This is the more to be regretted because certain species of Mitra, Fusus, &c., are recorded by him, most of the specimens being lost, and only a few preserved in the Museum of Practical Geology.

The writer's own collections from the gravels do not embrace more than thirty-five to forty species at present identified, others still having to be worked out, and explorations still being carried on; and his results are so totally opposite to the remarks of Professor Hull that he ventures to ask the Council of the British Association for the Advancement of Science for an additional grant to enable him to continue his researches into the age and extent of these gravels, the history of the early making of Ireland in its present form largely depending upon a solution of the question.

The fossils obtained will be shortly handed over to the National Collection as soon as they are worked out in detail, and are in number about as follows:—

	Sp.
Wexford Manure Gravels	35–40
,, Loams (Ballygeary)	30–35
Killiney Bay	30–
Balbriggan	20–

Your reporter respectfully asks for a further grant of 15*l*., the former grant being exhausted.

Seventh Report of the Committee, consisting of Mr. R. ETHERIDGE, Mr. THOMAS GRAY, *and* Professor JOHN MILNE (*Secretary*), *appointed for the purpose of investigating the Volcanic Phenomena of Japan.* (*Drawn up by the Secretary*, 1887.)

THE GRAY-MILNE SEISMOGRAPH.

THE seismograph, which in 1883 was constructed partially at the expense of the British Association, still continues to give satisfactory results at the Imperial Meteorological Observatory in Tokio, where it is installed as the reference instrument.

In the following table its records, as published in the daily papers and the official reports, are given for the last year. The time is noted for a particular wave in a disturbance. The period or time taken to describe one of the principal vibrations is given in seconds.

The numbers in the amplitude column give the total range of motion, or the double amplitude, in millimetres.

Catalogue of Earthquakes recorded at the Meteorological Observatory, Tokio, between May 1886 *and May* 1887, *by the Gray-Milne Seismograph.*

1886.

No.	Month	Day	Time	Period in secs.	Amplitude in m.m.	Principal direction	Duration
			H. M. S.				M. S.
666	VI.	3	3 6 37 P.M.	—	—	S.E. or N.W.	—
667	,,	11	1 45 44 P.M.	0·6	0·2	S.S.E. or N.N.W.	·45
668	,,	14	6 25 19 P.M.	—	—	S.E. or N.W.	25
669	,,	,,	6 56 9 P.M.	0·3	0·4	S. 45° E.	1 10
670	VII.	2	0 33 6 P.M.	1·2	0·7	S. 26° E.	3 30
			vertical motion	0·7	0·2		
671	,,	23	0 57 0 A.M.	1·9	0·5	S. or N.	1 4
672	VIII.	3	2 11 45 A.M.	—	—	E. or W.	20
673	,,	9	10 24 0 A.M.	2·4	0·7	E. or W.	3 0
674	,,	10	8 53 43 P.M.	0·8	0·2	E. or W.	17
675	,,	11	9 52 33 P.M.	1·2	0·2	E. or W.	2 0
676	,,	12	2 54 45 P.M.	—	—	—	—
677	,,	13	11 40 26 P.M.	—	—	—	—
678	,,	19	0 9 23 A.M.	0·4	0·2	E. or W.	14
679	,,	29	8 34 54 P.M.	—	—	N.N.E. or S.S.W.	20
680	IX.	6	0 38 53 P.M.	1·0	0·2	E.S.E or N.N.W.	10
681	,,	12	8 43 22 P.M.	1·0	0·3	E. 20° 20′ N.	1 0
682	,,	15	3 9 23 A.M.	very	slight	E. and W.	26
683	,,	16	1 2 57 P.M.	,,	,,	S.E. and N.W.	40
684	,,	20	abt. 1 40 0 P.M.	—	—	—	—
685	,,	21	8 17 9 P.M.	very	slight	E. and W.	1 5
686	,,	30	10 36 8 A.M.	,,	,,	S. and N.	—
687	X.	4	1 35 25 P.M.	0·5	0·3	E. and W.	30
			vertical motion	—	0·3		
688	,,	22	3 49 14 A.M.	very	slight	S. and N.	50
689	,,	25	10 11 18 P.M.	0·8	0·3	E.S.E.–W.N.W.	39
			vertical motion	very	slight		
690	,,	30	4 35 17 P.M.	,,	,,	E.–W.	10
691	XI.	1	5 13 5 A.M.	0·4	0·3	E. 34° S.	10
692	,,	2	8 21 46 A.M.	very	slight	S.E.–N.W.	30

CATALOGUE OF EARTHQUAKES—(*continued*).

No.	Month	Day	Time	Period in secs.	Amplitude in m.m.	Principal direction	Duration
			H. M. S.				M. S.
693	XII.	4	2 0 39 P.M.	0·5	0·4	S.E.–N.W.	2 10
			vertical motion	0·5	0·4	—	—
694	,,	6	0 45 46 P.M.	very	slight	—	—
695	,,	8	11 58 16 P.M.	0·5	0·2	E. 27° N.	35
696	,,	11	10 16 25 P.M.	1·5	0·2	E.–W.	28
697	,,	12	10 11 55 P.M.	2·2	3·5	E. 37° S.	4 30
			vertical motion	very	slight		
698	,,	21	3 7 2 A.M.	,,	,,	S.–N.	—
699	,,	26	5 48 5 P.M.	0·2	1·0	N. 35° W.	30
			vertical motion	very	slight		
700	,,	29	11 5 43 A.M.	0·6	0·4	E.S.E.–W.N.W.	45
			vertical motion	very	slight		

1887.

No.	Month	Day	Time	Period in secs.	Amplitude in m.m.	Principal direction	Duration
701	I.	15	6 51 59 P.M.	2·3	19·2	E. 34° N.	10 0
			vertical motion	0·8	5·5		
702	,,	,,	7 36 40 P.M.	0·4	0·5	E. 36° N.	1 30
			vertical motion	very	slight		
703	,,	16	10 16 19 P.M.	0·4	0·7	E.–W.	1 17
704	,,	,,	10 31 0 P.M.	—	—	—	—
705	,,	,,	10 54 18 P.M.	—	—	—	—
706	,,	17	8 59 34 A.M.	—	—	—	—
707	,,	21	11 46 43 P.M.	—	0·2	E.–W.	25
708	,,	23	9 16 55 P.M.	1·0	0·2	S.S.E.–N.N.W.	35
709	,,	24	10 40 50 P.M.	very	slight	—	—
710	,,	28	3 54 8 P.M.	—	—	S. or N.	20
711	II.	2	2 8 14 P.M.	2·0	0·4	W. 26° 30′ S.	2 30
712	,,	22	1 30 48 A.M.	—	—	—	—
713	,,	25	3 41 0 P.M.	—	—	E. or W.	—
714	,,	27	8 11 11 A.M.	—	—	E. or W.	—
715	III.	2	5 33 21 P.M.	—	—	—	—
716	,,	10	1 31 37 P.M.	0·8	1·0	S. 59° 30′ E.	20
717	,,	20	11 32 56 P.M.	—	—	N. or S.	—
718	IV.	4	8 46 0 A.M.	—	—	N.E. or S.W.	—
719	,,	9	11 49 54 A.M.	—	—	E. or W.	—
720	,,	,,	3 1 54 P.M.	—	—	E. or W.	0 15
721	,,	15	10 18 0 A.M.	—	—	S. or N.	—
722	,,	16	3 41 55 A.M.	1·6	0·3	S. 37° 30′ E.	1 0
723	,,	18	11 25 0 P.M.	—	—	—	—
724	,,	27	9 30 38 P.M.	—	—	—	—
725	,,	29	11 12 10 A.M.	3·0	1·2	S. 22° E.	3 0
726	V.	2	11 25 40 A.M.	0·3	0·3	E. 33° N.	30
727	,,	5	2 35 10 A.M.	0·5	0·4	S. 38° 30′ W.	20
728	,,	6	3 49 58 P.M.	—	—	—	—
729	,,	7	7 12 3 A.M.	2·6	0·9	S. 29° 40′ E.	2 30
730	,,	,,	8 44 22 A.M.	—	—	—	1 50
731	,,	9	0 9 14 A.M.	3·0	0·3	S. or N.	2 0
732	,,	,,	4 33 7 P.M.	—	—	—	—
733	,,	17	4 19 44 P.M.	0·3	0·2	S. or N.	0 20
734	,,	21	9 46 20 P.M.	0·7	0·5	S. or N.	0 30
735	,,	29	0 50 57 A.M.	0·8	1·8	S.E. or N.W.	3 25
736	,,	,,	1 10 44 A.M.	1·0	1·1	S.E. or N.W.	2 30
737	,,	,,	3 41 26 A.M.	—	—	E. or W.	0 35
738	,,	,,	6 47 21 A.M.	—	—	S. or N.	0 40
739	,,	,,	8 7 9 A.M.	—	—	—	—

Since 1883 several improvements have been introduced into the Gray-Milne seismograph, and the instruments embodying these improvements are now being manufactured by Mr. James White, of Glasgow. In the original form of the instrument, as with all instruments with which we are acquainted, after the occurrence of an earthquake the instrument required to be provided with a new recording surface and reset. Unless this was done successive earthquake-diagrams would be superimposed upon each other, and even a single earthquake, if its duration exceeded forty-five or sixty seconds, had the diagram of its later movements superimposed upon its first; a method of recording which often resulted in confusion. Further, the diagrams were written upon a surface of smoked paper or smoked glass to preserve which varnishing was a necessity. In the new form of instrument the horizontal and vertical motions are written in ink, side by side, upon a straight band of paper. Ordinarily this band of paper is moving very slowly beneath the syphon pointers of the seismograph. At the time of an earthquake the speed of the paper is automatically increased for a definite period, after which it is automatically slowed down to its ordinary rate. In this way earthquake after earthquake may be recorded without the intervention of the observer, whose only duty is to see that the instrument is supplied with paper and the clockwork wound. A separate clock, arranged to keep accurate time, impresses a mark on the paper ribbon every five minutes, and during an earthquake every second. This improved seismograph is fully described by Mr. Thomas Gray, who has taken great pains to perfect the apparatus, in the 'Philosophical Magazine' for April 1887.

The importance of the instrument in its present form for the investigation of special seismological problems—such, for instance, as the relation of the 'Uri Kaishi,' or 'return shake,' which apparently succeeds all large disturbances to the disturbances which precede them—is evident to all who have given attention to earthquake investigation.

Remarks on the Earthquakes of 1886–87.

From the preceding list it will be seen that between the end of May 1886 and May 1887 seventy-four earthquakes were recorded at the Meteorological Observatory in Tokio. On the low ground in the same city it is probable that a slightly greater number were sensible, and in Yokohama, sixteen miles distant, which appears to be nearer to the origin of many of the earthquakes felt in Tokio, the number may have been still greater. During the two preceding years the number of disturbances recorded in Tokio were respectively seventy-three and fifty-six.

In 1886, as recorded by the 600 post-card stations distributed through the empire, 472 earthquakes were felt, and for each of them the Earthquake Bureau, which is a branch of the Meteorological Department, has drawn a map. I trust that at a future date I may be enabled to give the British Association an epitome of the results obtained from these observations, similar to that which I had the honour of presenting in 1886.

In looking at the catalogue published in this report, and also at the catalogue in the report for 1886, it will be noticed that there are several records of vertical motion, which is a component of earthquake movement about which we as yet know but very little. From these records it appears that the vertical motion relatively to the horizontal is very quick, so that two or three vertical movements are superimposed as ripples on a horizontal wave. Professor K. Sekiya, in a model made of bent wire

showing the path of an earth-particle as deduced from an earthquake diagram, called attention to this fact. Further, it appeared that the motion upwards was greater than the motion downwards. I have previously drawn attention to the shortness in period of vertical motion in artificially produced disturbances (see Report for 1885), and also as exhibited in the preliminary tremors of an earthquake, which are probably also vertical in direction. It is also probable that the sound-wave of earthquakes owes its origin to the rapidity of these movements, which are more marked where the strata are hard, and that many animals, like horses when lying down, pheasants, geese, frogs, &c., feeling these preliminary vertical movements, often exhibit symptoms of alarm from ten to thirty seconds before many earthquakes are felt by human beings. I have recently communicated a special note on this subject to the Seismological Society.

The severe earthquake of January 15.—By reference to the preceding catalogue it will be seen that on January 15, at 6h. 51m. 59sec. P.M. an earthquake, having a range of motion of 19·2 millimetres and a period of 2·3 seconds, was felt in Tokio. Its duration was ten minutes, an interval of time which probably includes the '*Uri Kaishi*,' or 'return shock.' Professor K. Sekiya has read a special paper before the Seismological Society about this disturbance, and I myself have communicated observations on the same to our local papers. Thirty-six seconds after the commencement of the motion Professor Sekiya observed a maximum motion of 21 m.m. In Yokohama, 16 miles to the S.W., a motion of 36 m.m. was recorded. The motion was most severe along a line about 30 miles in length, running westward from near Yokohama.

In Tokio the motion was slow, easy, and of considerable range, the sensation being not unlike that upon a boat moved by a gentle swell.

Billiard balls rolled to and fro upon their tables, and a distinct feeling of nausea was experienced by very many. The slowness in period I take to be due to our distance from the origin. Sometimes earthquakes have been so long in their period that they have moved Tokio back and forth almost unknown to many of the inhabitants, the only record of the motion being that recorded by seismographs and observations made on swinging lamps and objects like pendulums. Near the origin there were small landslips, and the water in certain wells of an 'artesian character' was decreased or increased. A rumbling preceded the disturbance, and during the night five more shocks were felt. Thousands of houses Professor Sekiya reports as damaged, those which suffered most being the frame houses with a stone facing, the movement of the timber throwing out the facing. In my own house, which is of timber faced with brick and stone, a similar but slighter effect was produced. In Yokohama the damage was, as usual, amongst the chimneys, the falling of which through the roof and various floors in certain cases created considerable damage. These chimneys, so far as I am aware, in all, or nearly all, cases were new chimneys, built partly for the sake of appearance and with a total disregard of the experiences of 1880 and the recommendations repeatedly expressed by the Seismological Society. Chimneys which were short and thick, without heavy ornamental copings, and not compelled to follow the vibrations of the structure to which they belonged, although situated in places which are known to be extremely dangerous, did not suffer. In my own mind it is certain that if the disturbance of January 15 had visited a city like Naples or London the destruction would have approached that which recently created so much havoc in the Riviera.

I wish to lay stress on this, because engineers and others judging of Japanese earthquakes by the amplitudes of motion which have been published, which, so far as I am aware, have only been published by observers in Japan, cannot furnish any ideas of relative intensity, and from the amount of damage we sustain refer to the earthquakes of this country as being 'mild in character,' 'mere tremors,' &c., while those of Ischia and other places in Europe are severe. (See, for example, Construction in Earthquake Countries, 'Proceedings of the Institute of Civil Engineers,' vol. lxxxiii. Pt. I.) In Japan we suffer but little damage on account of the nature of our buildings, but now that many *ordinary* European buildings are springing up the damage will probably increase. Earthquakes like the one here referred to occur in Japan as pointed out by Professor Sekiya about once a year, while near Tokio they are experienced every few years. Still larger earthquakes have hitherto recurred near to Tokio and Yokohama every thirty or fifty years. The following are the dates of the more important of these disturbances: A.D. 1293, Kamakura, a city near to the origin of the last earthquake, was destroyed, and 30,000 lives were lost. Others occurred in 1419, 1433, 1435, 1495, 1510, 1589, 1633, 1647, 1649, 1650, 1683, 1703 (when there was shaking for 200 days, and 100,000 people killed), 1707, 1771, 1772, 1783, 1794, 1812, 1853, and 1855.

Sounding Asama Yama.—Asama Yama is an active volcano about seventy-five miles N.W. from Tokio. It was last in eruption in 1870, and it is always violently steaming. I first ascended this mountain, which is about 8,800 feet in height, in 1877. At that time the crater, which has the appearance of a bottomless pit with perpendicular sides, was audibly roaring and belching forth enormous volumes of sulphurous vapour. The drifting of these vapours across the snow rendered it extremely bitter. Some of this snow was liquefied and carried to Tokio for chemical examination. The examination only yielded pure water, whatever it was that had given the snow its peculiar taste having probably been evaporated during liquefication. My next visit to Asama was in the spring of 1886. One of the chief objects of this expedition was to satisfy a curiosity which had arisen with regard to the depth of the crater. Many visitors to the summit reported that at favourable moments, when the wind had blown the steam to one side, they had been able to see downwards to an enormous depth. One set of visitors, who had remarkable opportunities for making observations, were convinced that if the crater was not as deep as the mountain is high above the plain from which it rises (5,800), it must at least be from 1,500 to 2,000 feet in depth. Although I had provided myself with sufficient wire and rope to solve this problem, owing to the inclemency of the weather and the quantity of snow then lying on the mountain, the expedition proved a failure. One of our number had to give up the attempt to reach the summit at about 6,000 feet above sea-level, while I and my remaining companion only reached it with great difficulty. Our stay was very short. The wind, which was at times so strong that we were often compelled to lie down, rendered it impossible to approach the crater, and after a few minutes' rest we beat a retreat, worn out with fatigue, across the snow-fields, towards our starting-point.

Two months after this a visitor who ascended the mountain by moonlight reported that the crater was only 200 feet in depth, and that at the bottom there was a glowing surface. A second visitor, Colonel H. S.

Palmer, R.E., estimated the depth as being between 500 and 600 feet. This estimate was based on the convergence of the walls of the crater, which he saw to the depth of about 300 feet, and the diameter of the crater, which he estimated, by walking round a semi-circumference, as about 370 yards. Previous estimates of the diameter had been 200 yards, three-fourths of a mile, and 1,000 metres. The Japanese say that the periphery is $3\frac{3}{4}$ miles. These last estimates, as pointed out by Colonel Palmer, are nearly in the ratio of 10, 81, 85, and 150!

These wildly discordant results as to the dimensions of Asama, and the increasing curiosity on this question, led me, in conjunction with Messrs. Dun, Glover, and Stevens, to face the fatigue of ascending Asama for the third time. We left our resting-place (Kutskake) at the foot of the mountain at 4.30 on the morning of October 2, and in company with five coolies we reached the summit at 11 A.M. After a short rest we commenced our measuring operations, the general arrangements of which were entirely the suggestion of Mr. Dun. Before Mr. Dun made his suggestion the various schemes which were proposed would, to my mind, have been unpractical and unsatisfactory. One suggestion was to roll a cannon-ball, with a string attached, down the crater; another was to shoot an arrow carrying a string into the hole; a third suggestion was to fly a kite across the crater, &c., &c.

Mr. Dun's method, which I subsequently learnt was similar to a method devised by the late Mr. Mallet, was as follows:—First, a light rope some 500 yards in length was attached to a block of rock lying on a high portion of the rim of the crater. Next, this rope, which I shall call the cross-line, was carried round the edge of the crater for about 150 or 200 yards. Here a heavy brass ring was tied upon it, and through the ring was passed the end of a copper wire coiled on a large reel. This was the sounding-line. Close to the ring a string, which I shall call the guy-rope, was made fast to the cross-line. This being completed, the cross-line was then carried on round the rim of the crater until it reached an eminence, as near as we could judge, opposite to the point where the other end of it was attached to the block of rock. After this the line was jerked clear of pinnacles and boulders lying round the edge of the crater. The cross-line now formed two sides of a triangle, stretching across the crater from where the ring and lowering apparatus were to two points diametrically opposite to each other. By letting out the guy-rope, the cross-rope could be stretched until it formed a diameter to the crater, with the ring in the middle. The getting of these ropes into position was a matter of no little difficulty. First was the fact that clouds of vapours not only prevented us from seeing from station to station, but also from seeing far out into the crater. Secondly, on account of the hissing and bubbling noises in the crater itself, we could only communicate with each other by sound for short distances. And, thirdly, there was the difficulty of clearing the cross-rope from the ragged edges of the crater, which involved considerable risks in climbing. All being ready, word was passed along to haul on the cross-rope; and, as it tightened, the guy-line was let out, together with the sounding-line, running parallel to it, but passing through the ring. Owing to the twisting of the cross-line by tension, and the consequent revolution of the ring, the wire was broken, and the first attempt at sounding failed. This difficulty was overcome by attaching the guy-rope to the ring itself. Very luckily the sounding-wire, having been entangled in the cross-rope

by the twisting before it broke, the apparatus it carried was recovered. This apparatus consisted of an iron wire, to which were attached a number of metals of low fusibility, like antimony, zinc, &c., together with pieces of wood, india-rubber, sealing-wax, &c. By the melting, burning, or fusing of some of these, it was hoped to obtain a rough idea of the temperature. Above these came a small net containing pieces of blue and red litmus-paper, Brazil-wood paper, and lead paper. With the assistance of my colleague, Dr. E. Divers, I had planned a number of chemical tests; but from previous experience I had learnt the impossibility of carrying out anything but the simplest of experiments when working on the summit of a live volcano.

At the second sounding, at a distance of about 100 feet from the edge, bottom (side ?) was reached at 441 feet. The wire of metals, &c., came up without change, farther than the softening and bending of the sealing-wax. The automatic laboratory had a strong smell of the action of acid vapours. The blue litmus was turned red, and the lead paper was well darkened. Assuming the lead paper to have been blackened by sulphuretted hydrogen, then, as pointed out to me by Dr. Divers, the absence of this gas at the surface, and the presence of sulphurous acid, might be due to the decomposition of sulphuretted hydrogen by oxidation or by sulphurous acid in the presence of steam. The presence of sulphuretted hydrogen would indicate a relatively low temperature.

At the third sounding the line, which was a copper wire, gave way at a depth of about 200 feet, carrying with it a mercurial weight thermometer and other apparatus which I had reserved for what I hoped to be the best sounding.

The fourth and last sounding was made, as measured on the guy-rope, at a distance of about 300 feet from the edge. In this case, the line, which was strong twine, after striking bottom when nearly 800 feet of it had run out, suddenly became slack. On hauling up, 755 feet were recovered. The end of this line was thoroughly carbonised, and several feet were charred. Assuming that the guy-rope was paid out at an angle of 45°, we may conclude that the depth at this particular place was *at least* 700 feet. It is probable that the greatest depth is about 750 feet.

A final experiment was to attach a stone to the end of the cross-rope, and then throw it into the crater, with the hope of hauling at least a portion of it up the almost perpendicular face on the other side. Unfortunately the line caught, and, in the endeavour to loosen it, it was broken.

Before we left the summit we were very fortunate in obtaining views of one side of the bottom of the crater. This we did by cautiously crawling out upon an overhanging rock, and then, while lying on our stomachs, putting our heads over the edge. The perpendicular side opposite to us appeared to consist of thick horizontally stratified bands of rock of a white colour. The bottom of the pit itself was white, and covered with boulders and débris. Small jets of steam were hissing from many places in the sides of the pit, while on our left, where we had been sounding, large volumes of choking vapours were surging up in angry clouds.

After this we descended the mountain, reaching our hotel at 8 P.M., after 15 hours' absence.

The recorded eruptions of Asama took place in the years 687, 1124 or 1126, 1527, 1532, 1596, 1645, 1648, 1649, 1652, 1657, 1659, 1661, 1704, 1708, 1711, 1719, 1721, 1723, 1729, 1733, 1783, and 1869. This last eruption was feeble, but the eruption of 1783 was one of the most fright-

ful on record. Rocks, from 40 to 80 feet in some of their dimensions, were hurtled through the air in all directions. Towns and villages were buried. One stone is said to have measured 264 by 120 feet. It fell in a river, and looked like an island. Records of this eruption are still to be seen, in the form of enormous blocks of stone scattered over the Oiwake plain, and in a lava stream 63 kilometres in length.

EARTH-TREMORS.

Introductory notes relating to the work done in Italy.—During the past year considerable time has been devoted to a critical examination of the earth-tremor records obtained from the automatic tromometer described in the report to the British Association for 1885. These records, together with the results which they have furnished, will be published in detail by the Seismological Society of Japan. As an introduction to an epitome of the results obtained in Japan, a few words may be said respecting the work now in progress in the Italian Peninsula, where, through the efforts of Professor M. S. de Rossi, twenty-seven stations for the observation of microseismical movements have been established. At the central station in Rome a daily map is issued on which the following phenomena are indicated:

1. Isobars at 1 millimetre apart.
2. Microseismical activity in different parts of the kingdom.
3. The number and intensity of earthquakes.
4. The state of activity at volcanoes.
5. The state of hot springs.
6. The increase or decrease in the water of wells.

From the tabular matter accompanying the maps one can read the state of microseismic activity at any particular station, or the average state of activity for the whole kingdom for any particular day or for a whole decade of ten days, the conclusion having been arrived at in Italy that microseismical storms recur decadically.

JANUARY 1885.

	Days										
	1*	2	3	4	5*	6	7	8*	9	10	
DECADE I.—											
Medium microseismical .	1·42	2·23	2·32	1·68	1·77	2·26	1·70	1·63	1·33	0·61	
Number of shocks . .	4	3	3	3	4	3	3	2	3	4	
Maximum intensity .	5°	4°	3°	1°	4°	1°	2°	3°	1°	1°	
	Days										
	11	12*	13	14*	15	16	17*	18	19*	20*	
DECADE II.—											
Medium microseismical .	1·44	3·07	2·59	2·15	3·07	2·86	2·41	2·08	3·37	2·59	
Number of shocks . .	3	7	3	17	6	9	5	3	10	8	
Maximum intensity .	2°	3°	1°	3°	3°	1°	1°	1°	3°	2°	
	Days										
	21*	22*	23	24*	25	26	27	28*	29	30	31*
DECADE III.—											
Medium microseismical .	2·03	2·13	1·74	2·66	1·59	1·83	1·74	0·94	0·64	0·66	1·35
Number of shocks . .	19	4	4	14	19	16	9	6	1	2	6
Maximum intensity .	1°	3°	1°	8°	1°	1°	1°	1°	1°	2°	3°

As illustrative of this decadic recurrence I give the preceding table compiled from the notes of Professor Rossi as published in the 'Bullettino del Vulcanismo Italiano' (anno xiii. fas. 1–3, pp. 5–7).

The days marked with an asterisk are those on which, as referred to in the 'Bullettino,' there was the greatest activity. First, I fail to see that those days are the days of maximum activity, and even if they are they do not appear to repeat themselves at intervals which are strictly decadic. Considering that each decade is divided into three parts that there should not be a near correspondence is apparently impossible.

As residents in Japan cannot know the nature of the Italian work so well as those who are carrying it on in Italy, the chief object of this criticism is to gain information which may be of value in the tabulation of the work which in Japan is only now commencing. Another criticism which I bring forward refers to the relationship between the occurrence of tremors and the movements of the barometer. In Italy it has been observed that tremors are frequent and almost invariably accompany a low barometer. These tremors are known as *baro-seismic* movements, while those which occur during periods of high pressure are called *vulcano-seismic* movements. From an examination of a large series of the Italian maps it appears that there is a more general relationship between the occurrence of earth-tremors and atmospheric fluctuations than that which is implied in the name baro-seismic. The new law which I venture to put forward is that *tremors are at a maximum in the Italian Peninsula when the barometrical gradient is steep, no matter whether the barometer is high or whether it is low.*

Date	Mean micro-seismical intensity in Italy	Barometric fall per 300 geographical miles	Heights of barometer 300 miles apart—700
January 1, 1885	1·48	7	63–70
„ 2, „	2·24	6	63–69
„ 3, „	2·47	6	64–70
„ 5, „	1·84	4	64–68
„ 6, „	2·29	4	64–68
„ 7, „	1·89	4	63–67
„ 10, „	·53	1	64–65
„ 12, „	3·59	7	48–55
„ 13, „	3·03	6	44–50
„ 19, „	3·75	9	61–70
„ 20, „	2·79	10	54–64
„ 30, „	·75	3	63–66
February 3, „	2·80	9	54–63
„ 7, „	1·13	4	60–64
„ 15, „	·43	0 or 1	67–68
„ 16, „	·57	2	67–69
„ 23, „	·98	3	65–68
„ 24, „	·82	3	69–72
„ 27, „	·73	3	65–68
March 2, „	·88	1	59–60
„ 3, „	·71	1	62–63
„ 6, „	4·37	8	53–61
„ 7, „	4·04	8	54–62
„ 14, „	3·14	8	58–66
„ 16, „	·57	1	72–73
„ 17, „	·49	0	72–72
„ 20, „	1·14	4	51–55
„ 22, „	1·09	4	54–58
„ 29, „	·82	0	59–59
„ 30, „	·81	3·5	56–58·5
„ 31, „	·96	2	61–63
April 2, „	·54	1	58–59

As confirmatory of the above conclusion the preceding table for days when there has either been great or little microseismical disturbance has been drawn up. It shows the intensity of the tremors in Italy, the actual height of the barometer, and the gradient.

From an inspection of the table it will be seen that a low barometer, as on March 29, is not necessarily accompanied with unusual tremors, and that tremors only occur with a steep gradient.

A steep gradient is usually accompanied by wind, but, unfortunately, the means of comparing microseismical disturbances with the state of the wind is not given on the Italian maps.

Work done in Japan.—I will now give the general results derived from a set of records obtained from my automatic tremor-recorder. With but few omissions they extend from Jan. 13, 1885, to May 14, 1886.

(*a*) *General barometric analysis.*—With the barometer standing above the monthly mean tremors were observed 72 times, while they were not observed 143 times.

With the barometer below the monthly mean tremors were observed 105 times, while in 104 cases they were not observed. The observations apparently indicate that tremors occur rather with a low than with a high barometer; but even if the barometer is low it is as likely that tremors should not occur as it is that they should occur. The tables showing these results also showed that tremors were more frequent during the winter months—a fact which has often been noticed.

(*b*) *General wind analysis.*—Tables were prepared, showing for each month the number of times that tremors had been observed, or had not been observed, for different intensities of the wind. The general results arrived at showed that when the wind velocity was low it was seldom that tremors had been observed, but when it was high tremors were almost invariably observed.

With a wind velocity of 100–150 kilometres per 24 hours, tremors were observed in 28 per cent. of the times of observation.

With a wind velocity of 150–200 kilometres per 24 hours, tremors were observed in 27 per cent. of the times of observation.

With a wind velocity of 200–250 kilometres per 24 hours, tremors were observed in 24 per cent. of the times of observation.

With a wind velocity of 250–300 kilometres per 24 hours, tremors were observed in 34 per cent. of the times of observation.

With a wind velocity of 300–350 kilometres per 24 hours, tremors were observed in 50 per cent. of the times of observation.

With a wind velocity of 350–400 kilometres per 24 hours, tremors were observed in 35 per cent. of the times of observation.

With a wind velocity of 400–450 kilometres per 24 hours, tremors were observed in 54 per cent. of the times of observation.

With a wind velocity of 450–500 kilometres per 24 hours, tremors were observed in 57 per cent. of the times of observation.

With a wind velocity of 500–550 kilometres per 24 hours, tremors were observed in 38 per cent. of the times of observation.

With a wind velocity of 550–600 kilometres per 24 hours, tremors were observed in 60 per cent. of the times of observation.

With a wind velocity of 600–650 kilometres per 24 hours, tremors were observed in 44 per cent. of the times of observation.

With a wind velocity of 650–700 kilometres per 24 hours, tremors were observed in 62 per cent. of the times of observation.

With a wind velocity of 700–750 kilometres per 24 hours, tremors were observed in 100 per cent. of the times of observation.

With a wind velocity of 750–800 kilometres per 24 hours, tremors were observed in 100 per cent. of the times of observation.

(*c*) *Detailed wind analysis.*—The analysis now referred to extends over the period between Jan. 20 and May 14, 1886, or nearly four months. The wind observations with which the tremors were compared are given in the tri-daily weather maps prepared by the Imperial Meteorological Observatory. The wind scale runs from 0, or a calm, to 6, or a hurricane.

With the wind at 0 tremors were observed 10 times and not observed 16 times.

With the wind at 1 tremors were observed 53 times and not observed 47 times.

With the wind at 2 tremors were observed 54 times and not observed 49 times.

With the wind at 3 tremors were observed 37 times and not observed 16 times.

With the wind at 4 tremors were observed 12 times and not observed 1 time.

The percentage of times that tremors were observed with the wind in different states were as follows :—

Wind	at	0,	percentage	38
,,	,,	1,	,,	53
,,	,,	2,	,,	53
,,	,,	3,	,,	70
,,	,,	4,	,,	92

From this and the preceding analysis it seems that the stronger the wind the more likely it is that tremors should occur. The difficulty which here presents itself is to account for tremors sometimes occurring during a calm, and for the occasional absence of tremors during a wind. A partial explanation of these difficulties is obtained when we compare the occurrence of tremors with the barometric gradient, when we find that for each particular state of the wind when tremors have occurred the gradient has been steeper than the gradient for the same state of the wind when tremors have not occurred. Thus—

Wind intensity	Barometric gradient in millimetres per 120 miles	
	With tremors	Without tremors
0	2·3	1·9
1	2·9	2·1
2	3·0	2·1
3	3·6	2·9
4	4·4	3·0

From the above it appears that tremors are more closely connected with barometric gradient than they are with a *local* wind.

(*d*) *Detailed barometric analysis.*—The following table shows the relationship between the occurrence of tremors and the barometric gradient, irrespective of the force of the wind. The percentage of times that

tremors were observed out of the total number of observations made at any particular gradient are also given.

Barometric gradient per 120 m.	Tremors	Percentage	No tremors
0	2	28	8
1	28	57	21
2	42	44	52
3	40	50	40
4	22	88	3
5	20	71	8
6	5	100	—
7	3	100	—
8	—	—	—
9	1	100	—

The general conclusion to be drawn from this table is that tremors are proportionately more frequent the steeper the gradient.

(*e*) *The presence of tremors and the absence of wind.*—In the detailed wind analysis table *c* it was shown that there were tremors 10 times when it was calm, and 53 times when there was only a light breeze in Tokio. It was, however, also shown that although the wind was light the barometric gradient is relatively high. This led me to inquire whether there was not a strong wind blowing at a distance from Tokio, while in Tokio itself when tremors were observed it was calm. The results of the inquiry were as follows:—

First, in 6 cases out of the 10 when tremors were recorded during a calm, there were heavy winds blowing behind the mountains which shelter Tokio on its western and northern sides at a distance of 60 to 100 miles. In 3 cases there was a calm throughout Central Japan, but the tremors on these occasions were very slight.

Second, on 35 days out of 45 days on which the 53 cases of tremors were recorded with a light breeze, there was a strong wind blowing within 50 to 150 miles of Tokio. When the wind was blowing up from the S.W. at right angles to the ranges sheltering the plain of Tokio the tremors were very marked. On 10 days there was a calm in Central Japan, and the tremors which were recorded cannot be explained as the result of wind, neither do they hold any connection with a steep barometric gradient.

It is proper to note here that 44 days when there was a calm in Tokio, and no tremors, were also examined, with the result of showing that on 22 of the days there was a general calm in Central Japan, and on the 22 remaining days there was practically a calm. At one or two stations only was the intensity of the wind one or two, and even then at different stations it was blowing in contrary directions.

(*f*) *Absence of tremors and presence of wind.*—By reference to section *c*, it will be seen that there were sixteen cases when the wind was of strength 3, and one when the wind was of strength 4, and no tremors were recorded. In these instances if tremors are the result of wind, then tremors ought to have been recorded. In three cases the wind was local, while in the remaining cases the wind came in from the ocean.

(*g*) *Analysis of selected storms.*—A few of the more important tremor storms, some of which extended over thirty or forty hours, have been

drawn as curves, the ordinates of which represented the amplitude of tremor motion. These curves were compared with curves which represented the force of the wind and the height of the barometer in Tokio. After comparing these curves with each other it appeared that the microseismical disturbances showed the most varying relationship with the strength of the wind and the movements of the barometer.

(*h*) *Earth-tremors and earthquakes.*—Professor M. S. de Rosse has pointed out some remarkable instances when earth-tremors have been the precursors of earthquakes. From my records it appears that earthquakes have happened fifty-three times when there were no tremors, and thirty-three times when there were tremors. From this I conclude that earthquakes are just as likely to occur without tremors as with them.

(*i*) *Earth-tremors and the state of the wind in Central Japan in* 1885.—Central Japan is here meant to include all places within about 200 miles of Tokio. In this area there are eleven meteorological stations. If the wind has had a force of three or upwards at more than one of these stations it has been considered *windy*. When the wind has not exceeded two or one, even if wind of that intensity was blowing at all the eleven stations, it has been considered *calm*. An arbitrary division of days or periods into *windy* and *calm*, such as has here been followed, must necessarily result in absolutely separating the days which were truly windy from those which were truly calm. There are, however, a number of cases which might equally well be placed in either group.

In 1885 there were 945 weather maps which could be compared with the records of the tremor instrument. The results of the comparison were as follows:—

1. With no wind and no tremors there were . . . . 651 cases.
2. With no wind and tremors " " . . . . 51 "
3. With wind and no tremors " " . . . . 60 "
4. With wind and tremors " " . . . . 65 "
5. With a local wind in Tokio and no tremors there were 101 "
6. With a local wind and tremors there were . . . 17 "

On the assumption that tremors are due to the wind, then the second and third results are difficult to understand. These have therefore been carefully re-examined, with results as follows: In 17 out of the 51 cases of tremors occurring when there was no wind it is found that at these times it was moderately windy, and it is therefore possible that the tremors which were observed might have been due to wind. In 8 instances the tremors were accompanied by marked barometrical depressions, while in the 26 remaining cases the tremors were slight and of short duration.

In 51 cases out of the 60 cases when there was wind and no tremors it is seen that the wind was only moderate and of short duration. Most of these winds were afternoon sea-breezes, which possibly do not continue sufficiently long to produce tremors. In 9 instances of tremors they are the result of wind. These tremors ought to have been observed. The 945 comparisons may therefore be arranged as follows:—

1. With no wind and no tremors . . . . . . 651 cases.
2. With no wind and tremors 51 cases:—
   (*a*) Tremors possibly due to preceding wind . . 17 "
   (*b*) Tremors accompanying barometric depressions . 8 "
   (*c*) Tremors possibly of subterranean origin . . . 26 "

3. With wind and no tremors 60 cases:—

(a) Cases where tremors ought to have occurred	9	cases.
(b) Cases where it is doubtful whether tremors ought to have been observed	51	,,
4. With wind and tremors	65	,,
5. With local wind and no tremors	101	,,
6. With local wind and tremors	17	,,
Total	945	,,

In 1885 tremors were therefore recorded 133 times. The obvious explanation for 65 cases (50 per cent.) when tremors were very marked is that they were produced by stormy winds which were then blowing. In 34 cases (25 per cent.) the tremors *may* have been produced by stormy winds which had been blowing a few hours previously or by strong local winds. The remaining 34 cases (25 per cent.) *may* have been of subterranean origin. In these latter cases, however, *the tremors are feeble and of short duration, while when the tremors have accompanied wind they have been of considerable amplitude and of long duration.* That tremors are in great measure due to wind receives support from the fact that when it has been calm in Central Japan tremors which have always been very slight have only been observed in less than 5 per cent. of the times of observation.

Summary.

The preceding epitomised analyses apparently point to the following results:—

1. Earth-tremors are more frequent when the barometer is low than when it is high, but even with a low barometer tremors are not always observed.

2. With a steep barometric gradient tremors are almost always observed, but with a small gradient it is seldom that they are recorded.

3. The stronger the wind the more likely it is that tremors should be noted.

4. When there is a high wind in Tokio and no tremors such wind has almost invariably been local, or of short duration, or blowing in from the Pacific Ocean. Such winds are rarely accompanied by tremors.

5. When there has been no wind in Tokio, and tremors have been observed, in most instances there has been a strong wind in other parts of Central Japan. In the case of winds working up Japan from the S.W. the tremors in Tokio have been very marked, these being recorded in Tokio several hours before the arrival of the wind. Sometimes tremors appear to be due to a wind which had been blowing a few hours previously.

6. With a general calm in Central Japan it is extremely rare to observe tremors, and even if they are observed they are extremely slight.

7. Earthquakes and earth-tremors do not appear to be connected with each other.

Although the above conclusions are founded upon a fairly long series of observations and their importance is great, especially to all who are engaged in meteorological investigations, it is hardly yet justifiable to put them forward as established laws until the observations have been repeated. So far as my investigations have gone, it certainly appears

that the greater number of tremor disturbances are phenomena which originate upon the surface of the earth, and it is not necessary to look to subterranean agencies for their production. That tremors are produced by local winds acting upon trees and buildings is a phenomenon hardly requiring demonstration. We also know that artificially produced tremors can be propagated through ordinary soil to a considerable distance. Vibrations produced by stamping with the feet can be seen reflected in a dish of mercury at the distance of 100 feet. The vibrations produced by a railway train can be recorded at the distance of a mile.

The question now is whether winds blowing against high mountains, which at times, as I showed in my report for 1885, are in a state of vibration, produce a disturbance sufficiently intense to be felt at the distance of 100 miles upon plains where it is practically calm? Observations, so far as they have gone, appear to indicate this to be the case, and if it is so, then the movements of the ocean upon which wavelets and waves outrace the storms which originate them find a parallel in the movements of the land.

As a test of the accuracy of my conclusions I invited Colonel H. S. Palmer, R.E., to determine from a series of weather maps (257 in all) the days upon which tremors had occurred. The rules for his guidance were:—

1. With a general calm in Central Japan tremors seldom occurred.
2. With a wind in Tokio and Central Japan, or with no wind in Tokio, but with strong wind in other parts of Central Japan, tremors might be observed.

On receiving Colonel Palmer's list I was agreeably surprised to find that *in* 54 *out of* 57 *cases when he reported that tremors ought to have been observed he was absolutely right, there having been tremors which were very marked.* In reporting 'no tremors' he was only wrong when slight tremors had occurred.

Report of the Committee, consisting of Mr. H. BAUERMAN, Mr. F. W. RUDLER, Mr. J. J. H. TEALL, *and* Dr. JOHNSTON-LAVIS, *for the investigation of the Volcanic Phenomena of Vesuvius and its neighbourhood.* (*Drawn up by* H. J. JOHNSTON-LAVIS, *M.D., F.G.S., Secretary.*)

FEWER changes have taken place in Vesuvius than the reporter has known to occur during any of the eight years the volcano has been under his observation, and even in the recent history of the mountain no such extent of regular action is indicated. The lava mentioned in the last report as flowing continued to do so in varying quantity, and about September 17, 1886, again reached the cultivated lands, destroying some trees at the southern end of the Somma ridge. During the latter part of the same month and the first half of October the amount of lava varied very much, as also did the activity. Sometimes after a few days of quietness with the lava high in the chimney so that the scoria stage persisted, a small cone of eruption would be built up at the bottom of the great crater formed during the summer; but as soon as greater activity declared itself, or the lava-level sank, the ash-forming stage prevailed, and the great crater formed during the summer was further enlarged. As all

these changes took place from the eastern depression, the crater rim assumed an irregular oval plan—the larger end being towards the east. Early in November the upper part of the eastern slope of the great cone showed a considerable rent, nearly on the site of that of 1881–2, and about half-way down the mountain another opening, from which issued some of the lava during the last two months, and near which it probably now issues and flows under cover to the Val d'Inferno, where it appears at the surface. In November there was also to be seen a new fissure on the crater-plain (1872) in a N.E. direction, whilst the long one running due west has become much more marked from the advanced decomposition of its edges by the escape of the acid vapours. From that time up to the present the lava has continued to ooze in a few small streams near the base of the great cone at the junction of the Val d'Inferno with the Pedimentina. In the meanwhile, with slight intervals, a cone of eruption has been built up gradually at the crater-bottom, whilst the inner sides of the latter were thickly lined by a mantle of scoria cakes. This is fairly well shown in the photograph exhibited, which is the only one of any interest amongst those taken this year.

Exhibited at the meeting is the first volume of 'Lo Spettatore del Vesuvio e dei Campi Flegrei,' published by the Neapolitan section of the Italian Alpine Club. It is a revival in name of a somewhat similar publication of some thirty years ago. Its object is to record and publish any scientific observations on the Neapolitan volcanic region. The present number contains memoirs by Professors Comes, Palmieri, Palmeri, Riccio, Scacchi, and the reporter. The latter memoir consists of the detailed observations on Vesuvius during a space of four years, illustrated by three figures and thirteen phototype reproductions of photographs, all being the work of the reporter. These photographs have been exhibited in Section C during the last three years.[1] It is the intention of the publishers to continue to issue numbers from time to time if sufficient support can be found to cover the expenses. While speaking of this part of the subject, the reporter has received much help from local friends, and is particularly indebted to Mrs. T. R. Guppy and Mrs. Lavis for carefully carrying on observations on the activity of Vesuvius during his absence or illness.

The fifth sheet of the geological map of Monte Somma and Vesuvius has been completed, and is exhibited at the meeting, whilst the sixth is nearly so, but owing to the outburst of cholera at Resina and some other of the Vesuvian communes the five or six other field days necessary to finish it were not obtainable. Even had this been the case there would have been insufficient time to make a clean copy for exhibition at this meeting. The sheet presented required much negative work in the valleys and on the slopes of Monte Somma, and the detail work on the southern part took much time. As a portion of this sheet has been worked at different times, and no account kept, it is difficult to estimate the number of field days, but it would be within the truth if placed at twenty-five.

The only work now remaining to finish the geological map may be summed up thus: about six field days to complete the last sheet; about one week's work in the Atrio del Cavallo to map in that region with its dykes on the three different sheets upon which it appears; and about six field days to different localities where new exposures, roads, and excavations have been made; so that the reporter hopes next year to exhibit the *whole* map in manuscript and, if possible, a printed copy.

[1] A copy of the volume is exhibited.

This year has been less favourable for adding to our knowledge of the subterranean structure of this volcanic district. The artesian well at Russo's factory at Ponticelli, which was in progress at the date of the last report, is now completed, and M. Chartier, the engineer who superintended the boring, has kindly placed at my disposal the working records and specimens, which I hope to describe in detail elsewhere. Marine sand, tuff, and other clastic materials were traversed to a depth of 58 metres, and from that point to 103·4 metres beds of rather coarse doleritic lava were met with. The lavas repose on strata of ash, lapillo, and pumice, and at a depth of 180·6 metres sand and leucitic (?) breccia were met with. The importance of this well cannot be overrated, showing as it does the interlapping of the trachytic ejections of the Campi Phlegreæ with the Vesuvian lavas, tuffs, and breccias, and proving undoubtedly that the site of the valley of the Sebeto was a deep bay of the sea long after the fires of Vesuvius had commenced to burn, and that this bay was in great part filled up by the fragmentary deposits from the Neapolitan volcanoes, or others washed down the slopes of Vesuvius, and above all the lavas of that volcano that poured as fiery torrents into the placid prehistoric bath of the Siren long before that mythical goddess or even the ancient Paleopolis were thought of by human mind. At San Giovanni di Teduccio, in a direct line from the last well to the seashore, and near the latter, another boring has been made by M. Chartier. After passing through 18 metres of sand with shells 8 metres of marl were met with, with tuff and sand to 34 metres. It is regrettable that no greater depth was reached, as it might also have struck the Vesuvian lava, as in the former case.

At Pisciarelli, on the N.E. flank of the Solfatara, once the site of the alum-water rivulet, an attempt has been made to dig a well and re-find the alum water. The well has reached a depth of 25 metres, and the water is at boiling-point; and even with two hand-fans the atmosphere has risen above 90° C., so that the day before writing this report (Aug. 17, 1887) the workmen refused to continue work; and as it is necessary to excavate another 10 metres the fight between human ingenuity and volcanic heat may afford us some interesting facts. The water found is an alkaline sulphur water, and not aluminous, as the reporter had forewarned the engineer, who would not believe that alum is a surface product of the higher oxidation of the sulphurous acid and the action of the resulting sulphuric acid upon the trachytic rocks.

The railway works at the back of Naples have been suspended for some months from financial difficulties, and the new drainage works have not brought anything new to light. At the Armstrong works at Pozzuoli only facts that confirm what is already known have been met with.

The reporter spent over a month of the early summer in studying the volcanic group of the Eolian Islands. The state of Vulcano after the late eruption seems to be very similar to what it is under ordinary conditions. The bottom of the crater is now inaccessible without a rope, as the lower half of the path was blown away by the late eruptive action. Stromboli, however, showed the most remarkable quiescence, explosions being only few and far between; and during a stay of $4\frac{1}{2}$ hours at the crater only three were sufficiently strong to project a few fragments of pasty lava.

It is the reporter's wish, as soon as the geological map of Vesuvius and Monte Somma is finished, to commence a series of experiments upon

the temperature of the lava and, if possible, of its specific gravity at different temperatures.

The reporter regrets to show less apparent work in the present report, but he can assure the Section that not less real work has been carried out.

Third Report of the Committee, consisting of Dr. W. T. BLANFORD, Professor J. W. JUDD, Mr. W. CARRUTHERS, Dr. H. WOODWARD, *and* Mr. J. S. GARDNER, *for the purpose of reporting on the Fossil Plants of the Tertiary and Secondary Beas of the United Kingdom.* (*Drawn up by the Secretary*, Mr. J. S. GARDNER.)

THE small balance carried forward from last meeting has been expended in visiting the localities in which fossil plants have previously been met with.

The beds near the pier at Bournemouth seem more than usually inaccessible, but a fall from the cliff has brought down some of the dark clays, and in these were parts of a large feather palm and other leaves. I was fortunate enough, however, to secure at the west end of the cliffs a new species of *Acer* and a fine leaf of *Dryandra acutiloba*, really a *Myrica*, a rare leaf at Bournemouth, and one of the few that extend upward from the Lower Bagshot into the Bournemouth horizon.

I have again visited Alum Bay, but the pipe-clay on the shore has become still more diminished, and there is no hope that any more fossil plant-remains will be obtained there in our time. No distinct plant-remains are obtainable from the same horizon at Whitecliff Bay, though I had some hope that this might be the case. The drought was unfavourable to collecting at Barton and Hordwell, where most interesting fruits are washed out during heavy rains, and I procured no plants during my visits there this year; but it favoured, on the contrary, collecting at Lough Neagh, by lowering the level of the lake, and I am able to add a new *Pteris*, an exquisitely preserved fruit, and many dicotyledons to the flora, and a *Paludina* to the fauna.

No plant-remains were obtainable this year at Reading, nor do any of the other brick-pits in which plant-remains have occurred seem in exactly a favourable state at the moment for collecting; so that it appears undesirable to ask for further grants for this purpose at present. The Lower Eocene floras are, however, still insufficiently known, and excavations at Bromley, or elsewhere in the Woolwich horizon, would, I anticipate, yield especially important results. In the meantime an enormous mass of material has now been accumulated, which will require years of patient research to digest. Advantage has been taken of the presence of that distinguished palæobotanist, the Marquis de Saporta, at our meeting to go through the drawings, numbering more than a thousand, that I have already made of the fossil plants so far collected. He is completely astonished at the richness of our Eocenes, and considers them to be unrivalled. The Reading and Bournemouth horizons contain plants which do not appear in Europe until much later Tertiary times, seeming to have passed very slowly across Europe towards Eastern Asia—which may be considered their present home—their chief affinities being with floras indigenous to that part of the globe, rather than with those of America and Australia, as hitherto supposed.

Report of the Committee, consisting of Professor T. G. BONNEY, Mr. J. J. H. TEALL, *and* Professor J. F. BLAKE, *appointed to undertake the Microscopical Examination of the Older Rocks of Anglesey.* (*Drawn up by* Professor J. F. BLAKE, *Secretary.*)

THE Secretary of the Committee reports that it has been thought desirable for the adequate examination of the questions which arise in connection with the crystalline schists and associated rocks of Anglesey to have a large number of sections—about 300—cut from specimens from various localities. The cutting and preparation of these have occupied so much of the year as not to have left adequate time for the detailed study they require.

A map is exhibited showing the localities from which the rocks from which slices have been prepared have been obtained. These are in nearly every part of the island where the older rocks occur, and certainly include examples of every important variety. For stratigraphical purposes, to show the distribution of the various types, which cannot be with certainty distinguished in the field, a still larger series would be desirable; but for general questions connected with the origin of these rocks the collection is probably sufficient.

These preliminary results obtained by the first examination will be liable to modification and correction when more time has been given to their study; but the following points seem fairly well established at present:—

1. The quartz rocks have two distinct origins; one group consists of ordinary beds of quartz sand which have been more or less compacted and foliated by the development of some chloritic or other mineral in the interstices, and the other group has the original quartz grains irregularly scattered and imbedded in quartz which has been developed in the rock itself, somewhat after the manner of the quartz in a vein.

2. Passages may be traced from true chloritic schists, in which the largest original sand-grains only are left here and there, into breccias, in which the matrix has not yet been crystallised to its full extent, but which remains in a dusty or granular state.

3. The presence of this green mineral, generally called chlorite, is characteristic of certain parts of the whole series of Anglesey rocks, whether taken from the newer or the older portions, though its amount and definiteness vary to a great extent.

4. This same chloritic mineral is characteristically combined with quartz in what one might almost call a micropegmatitic manner, except that the mineral is rather in rounded blebs, arranged in a botryoidal manner.

5. The less crystalline or dusty members of the series are often divided by narrow opaque lines of the finest dust running more or less parallel, but interosculating and undoubtedly produced since the first formation of the rock. The more crystalline the rock the more rare is it to find such lines in them.

6. The granitic and dioritic rocks, which are found associated with the schists or ashy rocks, more generally with the latter, are distinguished by the presence of accessory minerals, such as zircon, sphene, rutile, and apatite.

7. Any one of these rocks, whether granite, syenite, or diorite, or whatever they may be called, puts on a foliated character in places, usually towards the margin of the mass.

8. There are rocks in this old series of an essentially basaltic structure, *i.e.*, consisting of acicular crystals of felspar in a less differentiated ground mass.

9. The fragments which occur in the breccias of the series between Bangor and Carnarvon can mostly, if not entirely, be identified with rocks from Anglesey, including the above basaltic rock, except those which are derived from the felsites of the same series.

10. The limestones of the group are remarkably pure, having either a schistose or mosaic structure; they have, however, in some cases the interstices filled with hæmatitic dust, which, when quartz is present, forms jasper. The only exception to this purity is an oolitic limestone at Llanbadrig, in which oolitic grains, often grain within grain, are imbedded in the more crystalline calcite.

11. In connection with the felsites occurring on the mainland must be recognised a rock occurring, amongst other places, near Beaumaris, which may be called a felsite grit. It is truly clastic, and may be a cleaved rock containing foreign fragments; but the matrix is so entirely formed of felsitic material that it has the aspect of a true felsite.

12. The peculiar polarising tints which are characteristic of pressure are met with in many of the rocks, but their development is so sporadic, even in the same rock, that their significance cannot yet be completely determined: it is less common in the granitic and allied rocks than in the schist.

In order to carry on the investigation of these rocks to a conclusion the Committee desire to be reappointed.

Second Report of the Committee, consisting of Professors TILDEN *and* ARMSTRONG (*Secretary*), *appointed for the purpose of investigating Isomeric Naphthalene Derivatives.* (*Drawn up by* Professor ARMSTRONG.)

VALUABLE contributions to our knowledge of the naphthalene derivatives have been made during the past year by Bamberger, Cléve, Ekstrand, Forsling, Guareschi and Biginelli, and others; my own investigations have also progressed very satisfactorily: and from the results obtained it is more than ever obvious that the information to be derived from the study of naphthalene derivatives will be of considerable importance, as it will unquestionably serve to throw light on the nature of the changes involved in the formation of substitution derivatives generally and on laws of substitution.

Sulphonation of α-mono-derivatives.—The behaviour of α-chloro- and bromonaphthalene was referred to in the last report; that of α-iodonaphthalene has since been found to be precisely similar, as this compound yields the 1:4 sulphonic acid as main product together with an isomer. The latter, however, has not yet been obtained in sufficient quantity to satisfactorily determine its specific characters. The 1:4 sulpho-chloride crystallises in massive prisms, melting at 123°; bromine

at once displaces the sulpho-group in the acid, forming 1:4 iodobromonaphthalene (m.p. 88°).

α-Cyanonaphthalene yields an acid which forms well-characterised salts, &c.: this is undoubtedly an α-sulphonic derivative, as it is converted by fusion with potash into an *hydroxycarboxylic* acid, from which α-naphthol may be obtained by removal of carbon dioxide. The hydroxy acid appears not to be identical with the α-hydroxy acid prepared from α-naphtoic acid; if this be the case it is to be anticipated that, although the sulphonic acids prepared from α-naphtoic acid and from α-cyanonaphthalene are both α-α-derivatives, the one will prove to be the 1:1′ and the other (probably the cyano-compound) the 1:4′ derivative. In any case, however, the behaviour of α-cyanonaphthalene affords another example of the modification of the 'meta-law' which prevails in the benzene series in favour of the 'alpha-law' to which reference was made in the previous report. These experiments on α-derivatives have been made by Mr. S. Williamson.

Dichloronaphthalenesulphonic acids.—With the object of characterising the dichloronaphthalenes and in order to obtain more material for the determination of the laws of substitution, a systematic study of the sulpho-acids obtainable from the dichloronaphthalenes has been commenced and already extended to five of them by Mr. W. P. Wynne and myself; the examination of the dichloronaphthalenes melting at about 61°, obtained from various sources, has afforded results of special interest, which serve to throw light on the constitution of several of the compounds referred to in the previous report, and has also led to the discovery that two distinct dichloronaphthalenes have hitherto been confounded together.

1. It was suggested in the former report that the sulpho-acid formed from α-$C_{10}H_7Cl$ in small quantity together with the 1:4 acid was an α-α-derivative; if so, it should give either the 1:1′ or 1:4′ dichloronaphthalene on treatment with PCl_5. Actually, however, it is found to yield a dichloronaphthalene melting at about 61°—the melting-point of Cléve's θ-modification—thus proving it to be an α-β-derivative.

Now there is reason to believe that, as a rule, if a β-hydrogen atom become displaced it is one contiguous to an α-position which is already occupied; it is therefore probable that the dichloronaphthalene in question and the parent sulphonic acid are 1:2 derivatives. The acid obtained on sulphonating the dichloronaphthalene gave a sulphochloride melting at 113°.

2. The chloro-acid obtained as chief product on sulphonating β-$C_{10}H_7Cl$ was said by Arnell to yield a dichloronaphthalene melting at about 61° when distilled with PCl_5: on repeating the experiment, it was found that the product fused sharply at 65°. The sulpho-acid prepared from this dichloronaphthalene gave salts similar to those obtained from the acid prepared from the dichloronaphthalene discussed in the preceding paragraph, and its sulpho-chloride fused at 119°. A very small quantity of the products from α-$C_{10}H_7Cl$ was at disposal, but a very considerable quantity of those from β-$C_{10}H_7Cl$, which could therefore be carefully purified; and as the formation of a 1 : 2 derivative on sulphonating β-$C_{10}H_7Cl$ appears highly probable, it is believed that the slight differences observed were due to impurity in the products from α-$C_{10}H_7Cl$. It is thought desirable provisionally to term the dichloronaphthalene melting at 65° *homo-θ-dichloronaphthalene* $= \theta$-$C_{10}H_6Cl_2$, as it is probably a *homonucleal* compound.

3. On treating the ? β-disulphonic acid referred to in the previous report with PCl_5 a dichloronaphthalene is obtained which also melts at about 61°·5; this, however, yields a sulpho-acid distinct from that obtained from the dichloronaphthalene from β-$C_{10}H_7Cl$, the melting-point of the sulphochloride being 150°.

4. Cléve has recently described a dichloronaphthalene melting at 61°·5 which he prepared from dichloro-α-naphthylamine. On sulphonating this modification an acid is obtained which is identical with that prepared from the dichloronaphthalene from the ? β-naphthalenedisulphonic acid. It is proposed to provisionally term this dichloronaphthalene *hetero-θ-dichloronaphthalene* $= \theta'$-$C_{10}H_6Cl_2$, as there is reason to believe that it is a heteronucleal compound—probably it is 2':4 $C_{10}H_6Cl_2$.

5. It will assuredly be found on examining the two dichloronaphthalenes melting (?) at 61° prepared from Cléve's two nitro-β-sulphonic acids, that the one is the *homo-* and the other the *hetero-θ*-modification. That obtained from Bayer's modification of β-naphtholsulphonic acid is doubtless hetero-θ-dichloronaphthalene: the conclusion arrived at by Claus, that this acid is a 2:3 di-derivative is not only opposed to all that is known of the behaviour of naphthalene compounds, inasmuch as it involves the assumption that on sulphonating β-naphthol the second β-position contiguous to the hydroxyl becomes displaced; it is untrustworthy, as the dichloroquinone which he obtained may have been, and doubtless was, produced by the action of chlorine liberated during the process of oxidation; and there is reason to believe that the dichloronaphthalene corresponding to such an acid would be the ι-modification, which melts at 120°.

Isomeric change in the naphthalene series.—One of the most striking cases of isomeric change known is that of β-naphthylsulphate, $C_{10}H_7.OSO_3H$, into Schaefer's modification of β-naphtholsulphonic acid by mere warming on the water-bath ('Berichte,' 1882, p. 204). The conversion takes place in the absence of sulphuric acid, and with such ease that there can be practically no doubt that it is a true case of isomeric change; and it is not probable either that the sulpho-group becomes displaced and re-enters the molecule in another position, or that one molecule acts upon another so that an exchange of sulpho-groups is effected. This view is supported by the following more recent observations: first, that if bromo-β-naphthol be submitted to the action of SO_3HCl at ordinary temperatures, the resulting product contains very little of the sulphate $C_{10}H_6Br.O.SO_3H$, but chiefly consists of the bromonaphtholsulphonic acid which is formed on brominating Schaefer's naphtholsulphonic acid.

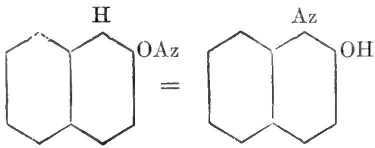
Again, if β-naphthylsulphate be acted upon by SO_3HCl without heating, not only is a second sulpho-group introduced, but that already present *spontaneously* changes its position: a *disulphonic acid* is thus produced, which is characterised by the readiness with which it parts with one of its sulphonic radicles being converted into Schaefer's monosulphonic acid; it is probable that the sulpho-group, which is easily displaced occupies the α-position contiguous to the OH group. The disulphonic acid here referred to itself undergoes isomeric change when heated, but the nature of the product is not yet finally determined.

Lastly, experiments have been made at my suggestion by Mr. E. G. Amphlett, in which the formation of the sulphate has been prevented by ethylating the naphthol; and it appears that, on sulphonating β-$C_{10}H_7.OC_2H_5$ at ordinary temperatures, by means of SO_3HCl, a mixed

product is obtained, consisting chiefly of an acid which most probably is the ethylated derivative of Bayer's naphtholsulphonic acid together with a small proportion of what is undoubtedly the isomeric ethylated derivative of Schaefer's acid; if, however, the product be heated on the water-bath, the former acid is converted into the latter.

These results afford evidence of a most interesting character, both the ease with which the conversion is effected and the variety of isomeric changes which are disclosed being remarkable. Special attention is being directed to the further elucidation of this branch of the inquiry.

Theory of the formation of azo-dye stuffs from β-naphthol.—A series of dye stuffs of considerable technical value are produced from β-naphthol and its sulphonic acids by interaction with diazo-salts. It is well known that in the case of β-naphthol itself the α-hydrogen atom contiguous to the OH group becomes displaced by the azo-group. This position appears to be free in all the sulphonic acids which afford azo-colours, and those naphthol derivatives in which it is not free appear to be incapable of forming such colours; it is therefore a legitimate inference that all azo-dyes derived from β-naphthol are formed by the introduction of an azo-group in the position indicated. The formation of such azo-colours in all probability involves the occurrence of isomeric change, the initial action consisting in the displacement of the H atom of the OH group by the azo-group Az, the compound thus constituted then undergoing change; thus—



In the case of such compounds the isomeric change apparently can take place only in the one direction, and on this account it is impossible to effect the introduction of the azo-group into any other position; if it were possible to displace some other hydrogen atom, azo-colours might well result.

Melting-points of the isomeric sulpho-chlorides.—The following numbers are interesting, as showing that the same change in composition does not always involve a change in physical properties of the same order; it will be noticed that, whereas in the 1:4 series the bromo-compound has a lower melting-point[1] than either the chloro- or iodo-compound, in the 2:3 series the bromo-derivative has the highest melting-point; the low melting point of the 2:3′ iodosulphochloride is also remarkable.

	β(1 : 4)	θ(?1 : 2)
α-$Cl.C_{10}H_6.SO_2Cl$	95°	127°
α-$Br.C_{10}H_6.SO_2Cl$	87°	151°
α-$I.C_{10}H_6.SO_2Cl$	123°	—
	ε (2 : 3′)	θ (?1 : 2)
β-$Cl.C_{10}H_6.SO_2Cl$	109°	130°
β-$Br.C_{10}H_6.SO_2Cl$	125°	147°
β-$I.C_{10}H_6.SO_2Cl$	92°·5	174°

[1] The melting-point cited is that given by Jolin; the others are from my own observation.

Report of the Committee consisting of Professor W. C. Williamson *and* Mr. Cash, *for the purpose of investigating the Carboniferous Flora of Halifax and its neighbourhood.* (*Drawn up by* Professor W. C. Williamson.)

Our researches during the past year in the immediate neighbourhood of Halifax have been less productive than usual; but this unfruitfulness has been in some degree compensated by successes in the surrounding district. Most notable amongst the latter has been the discovery of material enabling us to determine with absolute certainty the fructification of the Calamites. A fragment of a fruit was described in 1869 in the 'Memoirs of the Literary and Philosophical Society of Manchester,' peculiarities in the internal structure of which led the author of that communication to an important conclusion. None of the many Carboniferous fruits previously discovered displayed an internal structure that corresponded in any degree with that of Calamites. It was otherwise with the specimen just referred to, which exhibited what was so conspicuously absent elsewhere; hence the writer of the memoir in question inferred that it was a true Calamitean fruit. But though the evidence supporting this conclusion was strong, it was not sufficient to be absolutely demonstrative. It was therefore extremely satisfactory when, during the past spring, our young auxiliary, Mr. James Lomax, of Radcliff, brought to us a nodule, collected at Sunfield, Moorside, by Mr. Isaac Earnshaw, of Oldham, which contained seven or eight specimens of the strobilus described in 1869. The internal organisation of each of these new examples exhibits every feature seen in the older specimen, whilst they collectively furnish some new and important facts. Each of at least three of the strobili had attached to its base a portion of the peduncle of which the axis of the fruit was but a prolongation. In each case this peduncle is merely the end of the slender twig of a Calamite, identical in every respect with those of which we have obtained so many examples from the plant-bearing nodules of the Gannister coals. It has long been contended by some palæobotanists that these Arthropitean Calamites were gymnospermous plants. This interpretation has always been rejected by us. We have always insisted that they were Equisetiform cryptogams, and our new specimens demonstrate absolutely that such is the case. But the researches of the last twenty years have compelled us to modify some long-accepted notions. Under the title of the natural order Equisetaceæ, we regarded the living Equisetums as affording our standard type, by which all our primæval forms had to be judged. Now, however, a more comprehensive philosophy embraces both primæval and living forms in the large and varied group of the *Calamariæ*, of which the living Equisetums are but a degraded and somewhat aberrant branch.

We have obtained fresh information respecting the relations of Cordas, genera Anachoropteris and Zygopteris. One of these genera must be abandoned, their separation being no longer possible. We have also obtained many additional examples of cellular bodies within the interiors of tissues, cells as well as vessels, of various plants. Whether these are examples of Tylose, of Fungi, or of commensal Algæ is yet *sub judice.* We must also repeat an observation made at Birmingham last year. We possess many vegetable fragments which are known to us too imperfectly

to justify their immediate publication. On these, however, persevering research may be expected, sooner or later, to throw a fuller light. The number of such ill-understood forms increases, rather than diminishes, notwithstanding the success which has rewarded persevering inquiry in the case of several such, and which encourages the hope that the continuance of such inquiries will be yet further rewarded in like manner.

Fifteenth Report of the Committee, consisting of Professors J. PRESTWICH, W. BOYD DAWKINS, T. MCK. HUGHES, *and* T. G. BONNEY, Dr. H. W. CROSSKEY (*Secretary*), *and* Messrs. C. E. DE RANCE, H. G. FORDHAM, D. MACKINTOSH, W. PENGELLY, J. PLANT, *and* R. H. TIDDEMAN, *appointed for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation.* (*Drawn up by* Dr. CROSSKEY, *Secretary*.)

MANY details concerning erratic blocks not previously recorded have been received by the Committee during the past year, which throw considerable light on the important subject of their distribution.

It is not the business of the Committee to enter upon theoretical discussions. It may be useful, however, to point out a few of the salient facts, established (in the opinion of the writer of this report) more and more clearly by the researches undertaken by the Committee, and which must be fully covered by any theory that may be adopted respecting the Glacial epoch.

1. Erratic blocks occur in groups as well as in isolated positions; and these groups have well-defined and distinctive characteristics, and must not be confusedly mixed together. These groups sometimes contain erratic blocks from one locality; sometimes the blocks from various localities are intermixed, but in either case they have characteristics as distinct groups.

2. The distribution of a considerable proportion of erratic blocks is connected with the existing physical geography of Great Britain, as subjected to elevation and depression during the Glacial epoch. The evidence shows that many of them have travelled through the openings between and among our present hills, and that they have been diverted from their courses, or even blocked in their passage, by table-lands and eminences.

This fact, it must be noted, is at present stated with respect to a considerable proportion, and not the whole of them.

3. Erratic blocks have not all been distributed at one and the same time. Their occurrence has been recorded in the reports, in four positions, viz.:

(*a*) Beneath beds of clay, sand, and gravel.
(*b*) Embedded in beds of clay, sand, and gravel, thickly or sparsely.
(*c*) Resting upon beds of clay, sand, and gravel.
(*d*) Resting upon the native rock of the district.

It is clear that they could not have been deposited at the same time in all these positions.

4. Erratic blocks occur at various levels above the sea. These levels have been given in the reports.

5. Streams of erratic blocks have—

(a) crossed each other's paths, so that they have been more or less mixed;

(b) gone over each other under circumstances which have prevented any mixing;

(c) impinged against each other.

6. Erratic blocks have been distributed—

(a) from localities at a considerable distance from their present positions; as, *e.g.*, from Criffel to the Midland counties.

(b) from hills and eminences in their own immediate neighbourhoods.

7. With respect to the admixture of erratic blocks the facts recorded show the following differences:—

(a) Local erratic blocks are sometimes intermixed with those from a distance in considerable profusion.

(b) Groups of erratic blocks are sometimes found with a very slight admixture of rocks from the immediate locality, and have evidently travelled together as a group.

(c) Sometimes groups of erratic blocks contain rocks picked up along the course leading to the mountains from which they are derived; but this is by no means universally the case.

(d) In the neighbourhood of various hills purely local groups may be found.

The Committee have been greatly assisted by the formation of a Boulder Committee in connection with the Yorkshire Naturalists' Union, of which Professor Green, F.R.S., is President, and Mr. S. A. Adamson, F.G.S., the Hon. Sec.

Were a similar committee organised in each county the work of the Committee of the Association could soon be brought to a satisfactory conclusion.

Durham.

The following reports have been received (through the Yorkshire Boulder Committee) from Dr. R. Taylor Manson, Darlington.

Bulmer's Stone.—This is a block of Shap Fell granite.

It occurs on the west side of Northgate, at the edge of the flagged pavement opposite some old cottages, to which it is claimed as an appurtenance Nearly opposite the west end of Garden Street, Darlington, on Ordnance map. By compass circumference N. and S. 13 ft. 5 in.; E. and W. 12 ft. 8 in.; horizontal circumference ($1\frac{1}{2}$ ft. from ground), 13 ft. 5 in.; height from ground 3 ft. All portions visible are rounded. It has been moved. No striations; but some fractured surfaces smoothed. This boulder is known as 'Bulmer's Stone,' from old Willy Bulmer, who during the excitement of the Peninsular wars used to perch on it and read the newspapers aloud to the neighbours. The origin or age of the tradition contained in the following verse is unknown:—

In Darnton toune ther is a stane,
And most strange is yt to tell,
That yt turnes nine times round
When yt heares ye clock strike twell.

One hundred and fifty-seven feet above sea-level; marked on the 25-inch Ordnance map. Well shown on a photo of Northgate. It is isolated,

but there are both gravel and sand in the immediate neighbourhood. I believe that it rests on Glacial red clay, but the clay, sand, and gravel are irregularly distributed through the town; I think it is red clay there.

NOTE.—I have found Shap Fell granite several times in the bed of the Tees, at Pierce Bridge, and at Low Coniscliffe.

Erratic block at village of Sadberge, three miles N.E. of Darlington. The boulder was found in Glacial clay while excavations were being made for a reservoir. About 6 ft. 6 in. long, 4 ft. high. Estimated weight four tons. A wedge-shaped mass. The boulder is long-shaped, and has been moved. On what has originally been the base of the boulder there are innumerable striæ in the direction of the longer axis, and all parallel to one another. So far as I could ascertain (the incrustations of clay have not been removed) there were none of the crossings of striæ so generally seen. The striæ are confined to the original base. The rest of the surfaces are irregular and angular. The rock is a compact encrinital blue limestone, one of the Yoredale rocks, probably from Upper Teesdale, and is 218 ft. above sea-level. Too recently discovered for any legend, but no doubt traditions will gather round it, since, through the following circumstances, it will be known in the future as the 'Jubilee Stone.' Her Majesty is Countess of Sadberge, and the inhabitants of the village determined that one part of their Jubilee proceedings should be the dedication of this large boulder. It was removed from the excavation where it had been found to the village green, and on Jubilee Day a service was held in the village church. A procession from the church was then formed, escorted by a troop of yeomanry, an address on the history of Sadberge was given by the Rev. J. W. Baron, the stone was unveiled, and a *feu de joie* fired over it by the Hussars.

YORKSHIRE.

The Committee have received valuable information from the Rev. John Hawell, of Ingleby Greenhow Vicarage, Northallerton, who has examined the erratic blocks in his parish.

The sheets of the Ordnance Survey maps, which include the parish, are 24 and 43. The general height of the blocks above the sea-level is between 400 and 450 ft.

Most of the blocks examined are on the surface, in or near the beds of streams; others have been drawn out in draining. There is a thick tenacious clay in the district, with imbedded blocks, some of which at least are the same as those upon the surface. Further investigations, however, are needed to determine the relationship between the blocks upon the surface and those in the clay.

The erratic blocks are extremely numerous; Mr. Hawell has notes of 365, which he has already examined in his parish. It will be sufficient in this report to record examples of the chief varieties as a preliminary to further investigations.

The Committee have had the valuable assistance of Professor Bonney and Mr. C. T. Clough in the determination of the rocks. In identifying some of the more distant specimens the kind help of Messrs. B. N. Beach and T. Home has also been given.

The erratic blocks of Northallerton may be arranged in several classes:—

(A) *Blocks of local origin.*—The most numerous blocks of all on the surface are from the local Oolite.

No special record is needed of individual examples of these.

(B) *Blocks from the north of England.*—Next in abundance to the blocks of local Oolite are those from the basaltic dyke of the Cleveland district. Mr. Clough writes: 'This dyke has now been traced right across the country, N.W. to near Carlisle, and keeps much the same character throughout. There are also a few other dykes of much the same character in the N. of England.'

Marsh Lane, left of road, Ingleby, 1 ft. 6 in. × 1 ft. 1 in. × 4 in. Basaltic dyke of Cleveland district.

Ingleby Vicarage Garden—Dolerite, 1ft. × 10 in. × 6 in. Sub-angular. Extremely like one of the medium-grained varieties of the Whin Sill of Upper Teesdale and Weardale, and probably from the former district.

(C) *Blocks from the Cheviot Hills and adjoining districts of the south of Scotland.*—Ingleby Mill Dam, 1 ft. 6 in. × 8 in. × ? Sub-angular. Old andesite. Possibly from Cheviots, but not a common type there; and Mr. Clough thinks more probably from some of the other porphyritic areas in S. of Scotland.

Ingleby, 10 in. × 9 in. × 5 in. Porphyritic felsite. Might be from Cockburn Law (the Lammermoors) or from various other places in south of Scotland.

Ingleby—Wall on top of Vicarage Garden, 9 in. × 5 in. × 3 in. Sub-angular. Might well be from the Lower Old Red porphyrite district of the Cheviot Hills.

Right of road leading down to Ingleby Church, 1 ft. 6 in. × 1 ft. 10 in. Old augite-andesite. Like a type of the Lower Old Red porphyritic flow of the Cheviot Hills.

Ingleby Vicarage Garden, 1 ft. × 6 in. × 6 in. Porphyrite. A common type of dyke in the Lower Old Red porphyrite district of the Cheviot Hills.

Stream below Ingleby Church, 7 in. × 5 in. × 3 in. Sub-angular. Very like the Lowest Old Red porphyrite flows at the head of Coquetdale, Cheviot Hills. There are also dykes of much the same character in that district.

Stream below Ingleby Church, 10 in. × 7 in. × 4 in. Sub-angular. Old andesite. *Ibid.*

Ingleby Mill Dam, 1 ft. 1 in. × 6 in. × ? Like a common type of intrusive dyke in the Lower Old Red porphyritic district of the Cheviot Hills; but there are probably other exposures of similar rock in S. of Scotland.

Ingleby Mill Dam, 9 in. × 7 in. × 2 in. Sub-angular. Might well be from Lower Old Red porphyrite district of the Cheviot Hills.

Ingleby Mill Dam, 6 in. × 4 in. × ? Porphyrite. *Ibid.*

Ingleby Mill Dam, 10 in. × 6 in. × ? Porphyritic basalt. Might be from some of the similar basaltic blocks of the Border country.

Ingleby Mill Dam, 10 in. × 7 in. × ? Old augite-andesite. Like portions of lower porphyritic flow at head of Coquetdale.

Ingleby Mill Dam, 1 ft. 3 in. × 8 in. × 8 in. Old andesite. Extremely like a very common type of Lower Old Red porphyrites of Cheviots.

Ingleby Mill Dam, 1 ft. 4 in. × 1 ft. 2 in. × 1 ft. 1 in. Porphyrite. *Ibid.*

Ingleby Mill Dam, 1 ft. 1 in. × 11 in. × 5 in. Hornblendic porphyrite. A very common type of dyke in the Lower Old Red porphyritic district of the Cheviots.

Right bank of stream below Ingleby Church, 1 ft. 4 in. × 1 ft. 2 in. × ? Very like some of the Upper Old Red Traps of Kelso, S. of Scotland. Mr. Clough has noticed these rocks, mixed with Cheviot rocks in considerable quantity among Bridlington Bay boulders.

Ingleby Mill Dam, 1 ft. × 1 ft. × 9 in. Rounded. Compact basalt or possibly an augite-andesite. Might be matched from Lower Old Red districts of the Cheviots, but not a common type there. Probably from some other district in the S. of Scotland.

Ingleby Mill Dam, 1 ft. 2 in. × 1 ft. × 9 in. Volcanic ash. From Cheviots or adjoining volcanic district of S. of Scotland.

(D) *Blocks from more distant N. parts of Scotland.*—In stream just below bridge near Mr. Boyes' farm, 1 ft. 5 in. × 1 ft. 9 in. × 1 ft. 2 in. Very like an igneous mass in the Highlands, near the head of Loch Katrine and Loch Lomond.

(E) *Blocks from S.W. of Scotland.*—Stream at Ingleby, 10 in. × 6 in. × 6 in. Might be from the shoulder of Criffel.

(F) *Blocks from the Lake district.*—Blocks of Shap granite not at all uncommon.

Ingleby Mill Dam, 1 ft. 2 in. × 1 ft. × 9 in. Probably from volcanic series of Barrowdale.

Ingleby Vicarage Garden, 7 in. × 6 in. × 4 in. *Ibid.*

A number of other specimens are also analogous to the rocks of the Lake district.

The following reports have been furnished by the Yorkshire Boulder Committee:—

Dr. R. T. Manson, Darlington, reports upon the 'Stranger's Stone,' Deepdale, N. Yorkshire.

It is Shap Fell granite, 8 feet in height and 22 feet in circumference, on the bank of Deepdale Beck, about a mile up the stream from the point whence it flows into the Tees.

Semi-oval and smoothed; longest axis N.E. and S.W. Not embedded, but stands on a flat edge of the mountain limestone, which forms the bed of the stream, 550 feet above sea-level.

Probably moved by man from the higher ground above the river, since on the south-end face are two holes filled with lead as if for the insertion of iron hinge hooks for a gate, which in its present position would hang over the river.

Dr. Manson also reports upon an erratic block of Shap Fell granite at Low Field, three-quarters of a mile west of Cliff Hall, near Pierce Bridge, on the Yorkshire side of the Tees. The boulder is in the hedge side, on the east side of the field, about 200 yards from the river. It is about 70 feet above the river; 10 feet long on front face; 7 feet 4 inches from front to back. The boulder is sunk in the ground considerably; portion visible 4 feet above soil. Sub-angular; rounded top. Long-shaped. Longest axis N. and S. No groovings. An attempt has evidently been made to break it; holes have been cut in it with chisels. Two hundred and fifty feet above sea-level. Isolated; some beds of gravel not far off. Embedded, I think, deeply in the soil, which is heavy clay.

NOTE.—Another smaller boulder is lying to the left of the walk leading to Cliff Hall, about a mile west from the other. It is rounded, and about

3 feet long, with long axis E. and W. It has probably been moved by those who made the path near which it lies.

Mr. Wm. Gregson, Baldersby, Thirsk, records the following:—

Cattersty Sands, Skinningrove, 3 miles S.E. of Saltburn. Grey granite. Diameter, 3 feet. Rounded. No striations. Rests upon Lower Lias shales. On the shore.

Whorlton, 8 miles N.E. of Northallerton. Grey granite. Diameter, 3 feet. Sub-angular. Is striated. Rests upon Lias, 250 feet above sea-level.

Baldersby Park, 5 miles S.W. of Thirsk. Millstone grit; 6 feet by 3 feet. Angular. No striations. Rests on an outlier of Lower Lias, 90 feet above sea-level.

Elmire, 6 miles S. of Thirsk. Shap granite. Diameter, 2 feet. Sub-angular. No striations. Rests on Keuper sandstone overlaid by gravel, 60 feet above sea-level.

Mill Beck, Robin Hood's Bay (3 boulders), 10 miles N. of Scarbro'. Shap granite. Height 2 feet, circumference 9 feet. Sub-angular. No striations. Rests on Lower Lias on the shore.

Shap granite. Height 1 foot, circumference 7½ feet. Sub-angular. No striations. Rests on Lower Lias on the shore.

Shap granite. Height and circumference and other circumstances exactly similar to the last named.

Hutton Moor, 3 miles N.E. of Ripon. There are a good number of erratic boulders scattered over this moor, from 1 foot to 3 feet in diameter, a few of which are of grey granite, the remainder being chiefly millstone grit. They all rest on the Keuper sandstone.

The Rev. E. Maule Cole, M.A., informs the Committee that an immense number of boulders have been lodged on the top of Flamborough Head. On Beacon Hill are half a dozen of great size, mostly rounded, consisting of granite, whinstone, sandstone, and mica schist with garnets. These have probably been placed in their present position, but not moved far, as a neighbouring small ravine, called Hartindale Gutter, reveals the fact that the boulder clay in this locality is full of large boulders. On the neighbouring side of the ravine, leading down to Thornwick Bay, there is a boulder of cherty limestone lying on the surface, which measures 5 ft. 5 in. × 4 ft. 4 in. × 1 ft. 8 in.

A rounded boulder of sandstone 2 ft. 8in. × 1 ft. 9 in. × 1 ft. 2 in. projects in the side of the same ravine.

On Cliff Lane, Bempton, by the side of the road, is a group of eight large whinstone boulders, more or less rounded, which were removed from the adjoining fields to their present position more than seventy years ago. The average size is 3 ft. 4 in. × 3 ft. 4 in. × 1 ft. 8 in.

In the village of Bempton, by the blacksmith's shop, lies a whinstone boulder, 4 ft. 8 in. × 2 ft. × 1 ft. 6 in, and numerous others are visible in all directions.

Mr. C. D. Hardcastle reports upon 'The Greystone' in the parish of Leeds, one mile from the town on the side of the old highway to Bradford, opposite the northern end of Ventnor Street, on property belonging to the 'Pious Use Trustees.' Only 6 inches in height is now exposed above the causeway, and it projects 6 inches from a garden wall which is built over it. The base of exposed segment along the flags measures 2 ft. 10 in. Old inhabitants say it was formerly from 4 ft. to 5 ft. above

ground, and from 3 ft. to 4 ft. in diameter, but of irregular form. Its entire length is perhaps 7 or 8 ft. Thoresby in 1715 calls it 'a prodigious great stone.' Probably originally nearly rectangular. There are indentations in the stone, but not natural. It is composed of millstone grit, similar to that of Horsforth and Bramley Fall. The Rough Rock, of Horsforth, is about four miles distant on the same side of the river, and at a considerable elevation, some of the quarries being about 475 feet above the sea. The stone has probably come from there. Bramley is about three miles away on the opposite side, and at an elevation of 200 feet. The Greystone legend is that a huge giant hurled it from the Giant's Hill at Armley, about half a mile distant on the opposite side of the river, in proof of which statement the indentations of the giant's thumb and fingers are still to be seen. The Giant's Hill belongs to the flagstone series of the Lower Coal measures, whereas the 'Greystone' is millstone grit, 115 feet above sea-level. On the 6-inch Ordnance map. Lat. 53° 48′ 40″, long. 1° 34′ as 'Greystone.' An ancient boundary stone. Has served from time immemorial as boundary stone separating the manors of Leeds and Burley. Thoresby in 1715 quotes an old MS. survey, N.D: 'Lapis cinereus ingentis magnitudinis admodum antiquatus et vetustatus existens.' It rests upon yellow clay from 8 to 9 feet in thickness, below which there is Coal-measure shale.

NOTE.—According to Thoresby there was an old boundary stone called the Paudmire stone in Leeds main street (Briggate) similar to this boulder. This memorable stone was purposely sunk below the pavement as a supposed nuisance when that part was newly paved in the mayoralty of Mr. Samuel Hey (1703). The two stones are in a direct line with the Rough Rock of Horsforth, which is to the N.W.

Note upon the 'Hitchingstone,' Keighley Moor.—This huge block of millstone grit was described to the Committee by Mr. E. G. Spencer in 1874 as a 'boulder,' and the details concerning it will be found in the Report of the British Association for that year, p. 196.

A few years subsequently Mr. J. R. Dakyns, of the Geological Survey, stated in a letter to the Geological Magazine that 'in his opinion it is not a boulder'; and that 'it has no single characteristic of a boulder about it. It is not rounded or scratched, nor is it standing on end, nor in any such a way as to raise a suspicion of its having been removed.'

The Leeds Geological Association has, during the past year, thoroughly investigated the subject, and the secretary (Mr. Adamson) has described the results in a paper published in *The Naturalist*, November 1886, p. 333.

In this paper clear and satisfactory reasons are given in confirmation of Mr. Dakyns' opinion. The Hitchingstone cannot be regarded as an erratic, but is a portion of the 'Rough Rock' which originally covered the moors, and *in situ*.

Mr. R. H. Tiddeman, M.A., F.G.S., communicates (with the permission of the Director-General of H.M. Geological Surveys) the following report 'On the Distribution of Boulders from the Base of the Carboniferous Series at Norber and Malham Tarn, Yorkshire.'

Throughout the great area of Carboniferous rocks in the West Riding of Yorkshire there are hardly any rocks at the same time sufficiently well marked in character and limited in their area to give any good indications of the general distribution by drift transport of boulders from the original rock. Limestones, sandstones, grits, and shales, in all parts of

the series, bear a strong family resemblance to those from other parts, and so are no guide to ice movements during Glacial times.

There is, however, one rock which is an exception to this, and which gives a good starting-point followed by an excellent trail to the boulder hunter. This is a conglomerate which is to be found at the base of the Carboniferous limestone at Malham Tarn, and at Norber, near Clapham, Yorkshire. The conglomerate consists of a fine gravel of Silurian shale, the pebbles being compacted in a matrix of limestone. The former are of a greenish grey, the latter is of a creamy brown colour. When the rock is broken the fracture is a very clean one, passing through pebbles and matrix alike, and then to a casual observer it looks like a light mottled limestone. Where it has been subjected to the solvent action of weathering the pebbles stand out from the rock, giving well-marked oblong forms of which the surfaces are well preserved.

Conglomerate of this type occurs in a band across Malham Tarn, and showing best on its eastern margin, and also on the southern face of Norber, one mile E.N.E. of Clapham, a hill well known to geologists for its splendid train of Silurian boulders resting on the limestone. The conglomerate is no less interesting. It contains, besides the fine gravel, large boulders up to half a ton in weight, and interspersed with the gravel are corals, probably of the age of its deposition. Detached boulders of this rock range over a distance so far as I have seen them of 25 miles.

The nearest specimens worthy of note are a large boulder in the fields, $\frac{1}{4}$ mile S.E. of the Methodist Chapel in Malham—pointed out to me by Mr. Walter Morrison, M.P., and others, which he tells me were to be seen formerly along the road by the school on Kirkby Top. Some occur in walls a little to the east, between the first locality and Goredale Beck. These are mostly small.

A large boulder with quite a bed of loose gravel beneath it produced by its disintegration lies on the right branch of a stream running down south from the upper road between Malham and Settle on the moor about 200 yards from the road. This is more out of a north and south line from Malham Tarn than any of the others; which fact suggests that it may have come from Norber, but on the whole it is more likely from the Tarn, which lies N. 30° E., the nearest point of origin. Two other boulders appear to have been transported into Ingle Beck, south of the lane leading from Airton towards Holmes Gill Green, and have been built into walls there. These lie about S. 15° W. from the Tarn.

Beyond this point the boulders as we get further from the source are fewer and more scattered. Two more examples only have I seen, but these are remarkable. One was found in the banks of Pendle Water below the Old Hall at Roughlee—famous as the residence of Mistress Nutter as mentioned in 'Ainsworth's Lancashire Witches.'

This was a glaciated boulder of the conglomerate, about 14″ long, of oval form, and lay at about 600 ft. elevation. Scratches on Twiston Moor to the north pointing in this direction, and also in a straight line nearly for Norber, lie at an elevation of about 1,100 ft.; and if the boulder came from Norber it must have overridden this ridge, a continuation of the Pendle range, and crossed over ground 500 ft. higher and 150 ft. lower than its present site.

On the other hand, if from Malham Tarn it may have been carried south by the ice, along the Aire valley, to Bell Bush, and thence across

the watershed of England, north of Colne. This would be a much less up-and-down-hill route than the other.

The only other boulder of this rock I found was on Habringham Eans, about one mile south of Burnley. This was at an elevation of between 700 and 800 ft., and must have been carried by ice which was working its way towards Todmorden. This is the furthest; 23 miles from Malham Tarn, and borne along a line S. 10° W. If from Norber it has travelled about $24\frac{1}{2}$ miles along a general route of S. 10° E.

It will be seen in either case the route has been but very little deflected from a N. and S. line. These facts tend to bear out the truth of some statements made by me in 1871 to the Geological Society of London [1] that the general movement of the ice-sheet in this part of England, as shown by the boulders and by the glaciated rocks on which they lie, was *to the south*, parallel to the watershed of England and not away from it.

Staffordshire and Shropshire.

Mr. Fred. W. Martin furnishes the Committee with the subjoined catalogue of boulders in these counties previously unrecorded.

He is still engaged in their investigation, and will continue the catalogue in subsequent reports.

The collection is mainly a mixture of blocks from the Lake district and from the S.W. of Scotland, although a few scattered among them may be from the Cheviots.

So far as the present observations indicate the Welsh distribution has very sparsely, if at all, reached this district.

Shifnal to Tong.

1. At junction of road to Upton, hornblendic granite (gneissoid), very hard and heavy and porphyritic; Eskdale? Sub-angular; 2 ft. by 1 ft. 6 in. by 1 ft. 3 in.; rough surface.
2. On road just beyond stream. 'A syenite or diorite (slightly gneissoid), probably Scotch, not Lake or Welsh' (Bonney). Sub-angular; 2 ft. by 1 ft. 6 in. by 1 ft. 6 in.; rough surface.
3. In field, granite (of Criffel type); rounded; 2 ft. by 1 ft. 6 in. by 1 ft. 6 in.; rough surface.
4. Coarse Eskdale granite; rounded; 2 ft. 6 in. by 1 ft. 6 in. by 1 ft. 3 in.; rough surface.
5. In 'Spinney' on left. 'A fine-grained hornblendic granite, poor in quartz' (Bonney). Buttermere; rounded; 2 ft. by 1 ft. 6 in. by 1 ft. 6 in.; smooth.
6. Near gate, opposite last, augite andesite; angular; 2 ft. 6 in. by 2 ft. 6 in. by 1 ft. 3 in.; rough surface.
7. On left, just beyond last; epidote vein protruding. 'Felstone with epidote not unlike Bardon Hill rock, but probably Welsh' (Bonney). Sub-angular; 1 ft. 6 in. by 1 ft. 3 in. by 1 ft.; smooth and striated.
8. By entrance to lodge gates; coarse black granite (probably South Scotland); sub-angular; 3 ft. 6 in. by 2 ft. 6 in. by 1 ft. 6 in.
9. Under trees at junction of road to Long Norton; quartz felsite; square, broken edges; 3 ft. 6 in. by 3 ft. 6 in. by 2 ft. out of ground.
10. At opposite corner to last; granite of Criffel type; sub-angular; 3 ft. 6 in. by 2 ft. by 1 ft. 6 in.; rough.

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[1] *Quart. Journ. Geol. Soc.*, 1872, 'On the Evidence for the Ice-sheet in Westmorland,' &c.

11. On left near pool; granitite; two micas (black and white); two felspars (pink and white). 'Very likely from the area between Criffel and Dalbeattie' (Clough). Rounded; 2 ft. 6 in. by 2 ft. 6 in. by 2 ft. 3 in. out of ground; rough.
12. On right near bridge. 'A rhyolitic breccia, one of the Lake district porcelanite rocks; probably has come from Calder Fells, though may have come from the Duddon valley' (Lapworth). 5 ft. by 4 ft. by 2 ft. out of ground; squarish.
13. Near the last a granite of Criffel type; sub-angular; rough; 4 ft. 3 in. by 2 ft. 9 in. by 2 ft. out of ground.
14. On bridge over stream and used as a pier. 'Felspar hornblende and quartz; a quartz diorite or an exceptional fine grained felspathic hornblende granite. Probably Scotch' (Bonney). 3 ft. by 2 ft. by 2 ft 6 in. out of ground; rounded.
15. Next to above; granite of Criffel type; 3 ft. by 2 ft. by 2 ft. 6 in. out of ground; rounded.
16. Ditto 2 ft. 9 in. by 2 ft. by 2 ft. 3 in. out of ground; rounded.
17. As last, rounded; 3 ft. by 2 ft. by 2 ft. 3 in. out of ground.
18. Red granite (Eskdale ?); rounded; 2 ft. 3 in. by 2 ft. 3 in. by 2ft.
19. Granite; 3 ft. 6 in. by 3 ft. by 2 ft. 6 in.; rounded.
20. In field near Tong Church; granite, two felspars, orthoclase and oligoclase; free quartz; hornblende (probably South Scotland); 2 ft. by 1 ft. 6 in. by 1 ft. 3 in.; rough, rounded.
21. In road near last. 'Syenite or diorite (slightly gnessoid); probably Scotch, not Lake or Welsh' (Bonney). 2 ft. by 1 ft. 6 in. by 1 ft. 6 in.
22. Coarse Eskdale granite; 1 ft. 6 in. by 1 ft. by 1 ft.
23. Granite of Criffel type; small.
24. Same as No. 1; ditto; rounded.
25. Vesicular andesite lava with blebs of quartz. 'Might be from Lake district or South Scotland; or might be found anywhere by contact with intensely heated granite' (Lapworth). Under 1 ft. diameter; rounded; smooth.
26. Small block near last. 'A porphyritic felsite; many of the crystals resemble orthoclase. I don't know locality, but should say it was from an old lava flow' (Bonney). 1 ft. 6 in. by 1 ft. by 1 ft.
27. Near last; red granite (Eskdale?); small.
28. Granite of Criffel type; built into gate pier near church; 5 ft. by 2 ft. 9 in. by 2ft.
29. On bridge over stream near Tong Church; granite of Criffel type; 4 ft. by 3 ft. by 1 ft. 6 in.; sub-angular.
30. Near to same; *Ibid.* 4 ft. by 3 ft. by 2 ft.; sub-angular.
31. On opposite side of bridge. *Ibid.* 4 ft. by 2 ft. 9 in. by 2 ft. out of ground; rounded.
32. Ditto; 3 ft. by 2 ft. by 3 ft. out of ground; rounded.
33. In gateway to churchyard, used as a mounting stone. *Ibid.* 2 ft. 6 in. by 2ft. by 2 ft. 6 in. out of ground.
34. *Ibid.* Small.
35. On opposite side of gateway; *Ibid.* 3 ft. by 1 ft. 9 in. by 9 in.; sub-angular.
36. *Ibid.* Small.
37. *Ibid.* Small.
38. Built into wall. *Ibid.* 2 ft. by 1 ft. 3 in.
39. Opposite second lodge gates. *Ibid.* 3 ft. by 3 ft. by 2 ft.; sub-angular.
40. Hornblendic granite. 3 ft. by 2 ft. 6 in. by 2 ft.; rounded.
41. Near to the above. *Ibid.* 1 ft. 9 in. by 1 ft. 9 in. by 1 ft. 6 in.; rounded.

Codsall.

42. Near grocer's shop in lane, opposite Crown Inn; a porphyritic grey granite 2 ft. by 1 ft. 6 in. by 1 ft. 6 in.; rounded.
43. In ground, corner of Bull Inn; a porphyritic grey granite; 2 ft. by 2 ft.
44. At opposite corner of road; a porphyritic grey granite; 2 ft. 6 in. by 1 ft. 6 in.: by 1 ft. 6 in.; sub-angular.
45. Built into wall of coal-dealer's; fine-grained black granite; 2 ft. 6 in. by 1 ft 6 in.
46. Next to above and also in wall. Coarse red granite (Eskdale); 2 ft. by 1 ft. 6 in.
47. In circular recess. 'Old lava with olivine, serpentine, and augite; might be found anywhere in Borrodale, probably from Little Knot' (Lapworth). 1 ft, 3 in. by 1 ft. by 9 in.; angular.

48. Near to above; syenitic felstone might be from S. Scotland (Lapworth). 1 ft. 6 in. by 1 ft. 3 in. by 1 ft.; rounded.
49. Near to above. 'Hornblendic granite, most likely Scotch.' Under 12 in.
50. At corner of house up the road towards church; granite of Criffel type; 3 ft. 6 in. by 2 ft. 9 in. by 2 ft. 3 in.; squarish; angles rounded.
51. In narrow lane by above. *Ibid.* 1 ft. 6 in. by 1 ft. 3 in. by 1 ft. 3 in.; rounded.
52. Ditto. A bright grey granite. *Ibid.* 3 ft. 6 in. by 2 ft. by 2 ft. 6 in. out of ground; rough; rounded.
53. Granite in same lane, Criffel type; 1 ft. 6 in. by 1 ft. 6 in. out of ground; rounded.
54. In same lane. 'Felstone or possibly altered felspathic ash; similar rocks not unfrequent among older Palæozoic' (Bonney). 2 ft. by 1 ft. 6 in. by 1 ft. 3 in. angular; rough.
55. In same lane. 'Igneous; a felstone; might be Welsh or Lake district; a common kind in more than one region' (Bonney). 1 ft. 6 in. by 1 ft. by 1 ft.
56. In vacant ground side of road and opposite same lane; granite of Criffel type.
57. A fine-grained quartz felspar; grit probably Scotch; 3 ft. 6 in. by 2 ft. 6 in. by 2 ft. 6 in. out of ground; angular and squarish.
58. Fine-grained syenite (Eskdale). 2 ft. 9 in. by 2 ft. by 1 ft. 6 in.; rounded.
59. 'Felstone probably Welsh, but might be from the north, not very distinctive' (Bonney). 1 ft. 6 in. by 1 ft. 6 in.; smooth.
60. Granite of Criffel type; 2 ft. 6 in. by 2 ft. by 1 ft. 6 in.
61. *Ibid.* 2 ft. 6 in. by 2 ft. 3 in. by 2 ft. out of ground; rounded.
62. 'A coarse granitoid rock, in all probability from a node—I think most probably Scotch' (Bonney). 2 ft. by 9 in. by 1 ft. 6 in.
63. Same as 58. 2 ft. by 2 ft. by 1 ft. 6 in.
64. Granite of Criffel type; 2 ft. 6 in. by 1 ft. 6 in. by 1 ft.
65. Small block down narrow lane from church; a diorite.
66. A diorite by stream towards Gunston; syenitic felsite (Buttermere).
67. Against farm wall, Gunston; fine-grained Eskdale syenite; 2 ft. 6 in. by 2 ft. out of ground; sub-angular.
68. In hedge close by last. Mr. Clough says: 'Might be from Lower Old Red volcanic district of the Cheviot.' 3 ft. 6 in. by 2 ft. 6 in. on face.
69. Near same. Fine-grained hornblendic granite; 2 ft. 6 in. by 2 ft. by 2 ft. out of ground.
70, 71. On road to Brewood from same; two blocks. Granite of the Criffel type.
72. In hedge close to top of hill by fir trees; large block of porphyritic granite; 3 ft. by 2 ft. on face; squarish.
73. Large block of coarse grey granite in ditch opposite Bilheath farm; 5 ft. by 2 ft. 9 in. by 2 ft.; squarish and rounded.
74. A fine-grained quartz felspar grit; highly probably from Scotland; small.
75. Ditto. Near same. 'I think this to be really igneous and a variety of porphyrite, almost certainly Scotch' (Bonney). Small.
76. Very like No. 7, but crushed; small.
77. Top of hill at Oaken; a diorite; 2 ft. 6 in. by 2 ft. 3 in. by 1 ft. 6 in.
78. By farm-buildings, just beyond blacksmith's; porphyritic grey granite; 2 ft. 6 in. by 2 ft. by 1 ft. 6 in.
79. *Ibid.* 2 ft. 6 in. by 1 ft. 6 in. by 1 ft. 6 in.
80, 81. Coarse grey granite, broken and rounded; Criffel type; one piece; 2 ft. 3 in. by 1 ft. 6 in. by 1 ft. 9 in.; other piece 2 ft. 6 in. by 4 ft.
82. Near footpath. *Ibid.* 3 ft. 3 in. by 2 ft. 9 in. by 1 ft. 6 in.; squarish and rounded.
83. Small block in lane back of church; 1 ft. 6 in. by 1 ft. 6 in. by 1 ft. 3 in.; rounded.
84. Coarse grey granite, the wood Leasowes farm; 2 ft. 6 in. by 2 ft. by 1 ft. 3 in.; sub-angular.
85. In second field beyond same, against hedge; a porphyritic grey granite; 2 ft. 6 in. by 2 ft. 6 in. by 1 ft. 6 in.
86. Also slaty ash, much broken; 2 ft. 6 in. by 1 ft. 9 in. by 1 ft. 6 in.
87. Small block in clay pit by brickworks enclosed in a drift containing granitic pebbles; a porphyrite; small; sub-angular.
88. At junction of roads from Codsall Wood by stream. 'Might be from the Lower Old Red district of the Cheviot Hills' (Clough). Rounded; small.

89. Leaning against footbridge; a porphyritic granite; 4 ft. by 2 ft. 9 in. by 1 ft 6 in.; sub-angular.
90. Ditto. A porphyritic granite; 3 ft. 6 in. by 2 ft. 6 in. by 2 ft.; rounded.
91. A porphyritic granite; 2 ft. by 1 ft. 6 in. by 1 ft.; rounded.
92. Hornblendic granite, probably Scotch; 2 ft. by 1 ft. 6 in. by 1 ft. 6 in. rounded.
93. Porphyritic grey granite; 2 ft. 6 in. by 1 ft. 6 in. by 1 ft. 6 in.
94. Porphyritic grey granite; 2 ft. by 2 ft. by 1 ft. 6 in.
95. Porphyritic grey granite; 2 ft. by 1 ft. 6 in. by 1 ft. 6 in.; together with some small Eskdale syenites.

Gunston.

96. Small block, broken; a compactly crystalline hornblendic granite, probably Scotch.
97. Ditto. A porphyritic hornblendic granite, probably Buttermere; small.

WORCESTERSHIRE.

Mr. Westby reports the discovery of an erratic block of granite, of the Criffel type, in the neighbourhood of Worcester.

It was found at Cornmeadow, one-third of a mile S. of St. Claines Church, $2\frac{1}{2}$ miles N. of Worcester, about 20 yards from the road, and three-fourths of a mile E. of the river Severn. It rests upon the bed of gravel stretching from the river to the field. It is partly sunk under ground; the exposed part measures 3 ft. $\times$ 1 ft. 9 in. $\times$ 1 ft. 7 in. In shape it is semi-oval; the N. end and the sides are smooth and well rounded, but the S. projecting end is rougher.

Report of the Committee, consisting of Mr. S. BOURNE, Mr. F. Y. EDGEWORTH (*Secretary*), Professor H. S. FOXWELL, Mr. ROBERT GIFFEN, Professor ALFRED MARSHALL, Mr. J. B. MARTIN, Professor J. S. NICHOLSON, Mr. R. H. INGLIS PALGRAVE, *and* Professor H. SIDGWICK, *appointed for the purpose of investigating the best methods of ascertaining and measuring Variations in the Value of the Monetary Standard. (Drawn up by the Secretary.)*

ANALYSIS.

I. The Ideal Method; involving philosophical analysis.

II. The Practical Method; consisting of (A) one principal standard, based upon the items of national consumption; and (B) six auxiliary index numbers, based respectively on (1) wholesale goods in general, (2) imports and exports, (3) all existing purchasable commodities, (4) budgets of workmen's families, (5) general wages, (6) retail prices.

IT appears to the Committee that there are two ways of treating the problem proposed to them: two solutions, which may be distinguished as Theoretical and Practical. I. The theoretically perfect method is to distinguish analytically the different purposes which may be subserved by constructing a measure of the change in the value of money, and then to show what formula, what particular mode of combining the statistical data, is appropriate to each purpose. For example, one might distinguish as adapted to different special purposes two measures or standards which have been proposed by Prof. Sidgwick and Prof. Nicholson respectively.

The rationale of the former method is to compare the value at one epoch of the set of articles consumed (per unit of time) by the average person with the corresponding value at another epoch. The idea of the latter plan is to compare the value of all purchasable things whatever existing at one time with the corresponding value at another time. Several formulæ having been constructed, the last stage of the complete method would be to fill in the numerical values given by statistics.

It appears to us that the theoretical analysis which forms the starting-point of this procedure is quite indispensable. That this preliminary abstract, and one may almost say metaphysical discussion, is abstruse in a degree unusual in economical inquiries is an unavoidable peculiarity of the problem proposed to us. It is true that those who have entered on such discussions, like the votaries of speculative philosophy, may have

——found no end in wandering mazes lost.

But without such discussion we cannot find even a beginning in the present investigation. The first step must be at random, in the absence of a definite notion in what direction, towards what end, one ought to proceed. There can be no clue through the labyrinth of continually dividing ways. In comparing the purchasing power of money at two epochs, ought one to regard the prices of all commodities, or only some selected ones? In either case, is regard to be had to the amount of a thing which is in existence, or the amount which is used (per unit of time), or the amount which is sold? If some articles are to be selected, what articles? If the objects of national consumption, shall we include among these domestic service and residential houses? These are a few of the questions concerning which the investigator must be prepared with some answer.

It may well be that no discussion, however intelligent, will result in perfect agreement upon these questions. Those, however, who essay to deduce a methodical answer from principles generally received will be apt to diverge less violently from each other than those who embark upon the subject without chart and compass. Philosophical speculation may seem to play the same *rôle* in our particular problem as with respect to the general conduct of life. While the theoretical distinctions between systems are multiplied by philosophers, the practical divergence between the wise of every school tends to become minimised. On the other hand, uncultivated persons and nations are apt to erect into a rule of life some trivial practice recommended by any accidental association. Similarly, to compare interests of different magnitude, those who approach the monetary problem without some preliminary abstract discussion are likely to attach undue importance to the first view of the subject which presents itself. Some particular method of selecting and combining the data which has struck them impresses their imagination as *the* method. Founded upon no reason, their dogma is not amenable to reasoning. They occupy irremovably each his isolated position, incapable of persuading or being persuaded. The unity which is the character of science, and the collaboration which is necessary in practice will be wanting when rules are laid down by unreasoning caprice, instead of being deduced from generally admissible first principles.

While attaching this high importance to theory, and though we regard the speculative part of our problem as logically prior, we have not thought fit to put it first in our work. As in the cultivation of other practical

sciences which have roots stretching down into philosophy, it may be best to treat first those parts which are palpable and above ground. Indeed, it may be thought that the dialectical disquisitions to which we have alluded are better forwarded by dialogue than debate, and are more adapted to the study than the committee-room.

II. The practical method is directed rather to what is immediately attainable than what is ideally desirable. To those approaching the subject in this spirit it appears useless to multiply distinct formulæ, if in the present state of statistics the numerical data wherewith to fill in these formulæ are deficient. We might compare the existing conditions to the case of a ship whose compass, or whose antique method of steering by the stars, was so imperfect that the pilot never could be certain of not being out in his direction by one or two points. When intending to steer due north, he would be as likely as not to be, in fact, steering for N.N.E. or N.N.W. In such a case, to distinguish alternative routes differing in direction by only two or three degrees would be an operation of mostly theoretic interest.

Again, in the practical construction of a standard or measure of the changing value of money, regard must be had to the requirements of those for whose use the apparatus is principally designed. There is reason to think that a plurality of measures would embarrass the plain practical man; just as a translation which perplexes the unlearned by a variety of interpretations is not suited to become an authorised version.

These considerations point to the expediency of positing some one mode of utilising our data as *par excellence* the method, the best and principal measure of the change in the value of money. This pre-eminence of an unique method will not, however, be inconsistent with the use of certain confessedly auxiliary formulæ; bright inferior lights adapted to illuminate special portions of the industrial world, to subserve particular, though it may be extensive, interests.

Deferring the reasons for our preference, we express the opinion that, if some one method is to be distinguished as *the* method, that one must be of the sort which has been called the *Standard of Desiderata*,[1] and which may be thus described in general terms: 'summing up the amounts of money paid for the things consumed by the community at the old and the new prices respectively,'[2] and putting the ratio of the latter sum to the former as the sought measure or standard.

The question here arises, shall house-rent and the wages of domestic service be included among the items of the average budget? We opine —declining for the present to assign the grounds of our opinion—that both these items had better be excluded from the principal standard here contemplated.[3]

We may next consider the difficulty that the quantities of the articles consumed are not the same at the two epochs compared. We recommend that this difficulty should be met thus: Put, as the quantity which with least inaccuracy may be regarded as the one which is consumed at both periods, *the mean* between the two quantities consumed at the two epochs respectively. Thus, if we designate the selected commodities as A, B, C, &c., the expression which gives the measure of depreciation or the

[1] Horton's *Silver and Gold*, chap. iv.

[2] See Prof. Sidgwick's *Principles of Political Economy*, Book I. chap. ii. sec. 3.

[3] The rent of sites for business purposes and the wages of industrial labour are excluded by the definition of the *Standard of Desiderata*.

amount of money which at the posterior epoch is equal to a unit of money at the prior epoch is of the following form: [$\frac{1}{2}$ (quantity of commodity A consumed per unit of time at prior epoch + quantity of commodity A consumed per unit of time at posterior epoch) × average price of commodity A at posterior epoch + $\frac{1}{2}$ (quantity of B consumed per unit of time at prior epoch + quantity of B consumed per unit of time posterior epoch) × average price of B at posterior epoch + &c.] *divided by* [$\frac{1}{2}$ (quantity of commodity A consumed per unit of time at posterior epoch + quantity of commodity A consumed per unit of time at prior epoch) × average price of A at prior epoch + $\frac{1}{2}$ (quantity of B consumed per unit of time at prior epoch + quantity of B consumed per unit of time at posterior epoch) × average price of B at prior epoch + &c.]

The difficulty that new kinds and qualities of articles are continually entering into consumption is to be met in the manner suggested by Professor Marshall.[1] Frequent revisions of the 'standard' are to be made, say once a year, the purchasing power of money in each year being continually compared with what it was in the preceding year, after the manner above indicated. As soon as any new species of ware has made its appearance in two successive years, as soon as it figures both in a 'prior' and a 'posterior epoch,' the consumed quantity thereof (presumably not enormous within a year after the introduction of the new article) is to be entered as one of the items on which our calculation is based. Perhaps, however, there will not be much need of this refined adjustment for the rough standard which, by way of a first essay, we propose to construct for Great Britain.

In choosing the commodities proper to this purpose, we may take as our guide the 'Report on the Appropriation of Wages,' drawn up by Professor Levi for this Association in the year 1881. From the articles of national consumption specified in that Report, there should be selected those which have a certain degree of importance in respect both of bulk and also of the precision with which the returns of quantity and of price are in each case ascertainable in the existing state of statistics. The following list is provisionally offered: *bread, potatoes, butcher's meat, bacon, ham and pork, fish, cheese and butter, milk, fruit, sugar, tea and coffee, beer, spirits, wines, tobacco, boots and shoes, cotton goods, woollen goods, coal for domestic purposes.*

We reserve for a future Report the task of discussing each of these items on its merits; and of determining what finished products may be represented by means of articles which enter into their production, such as coal and iron. It must suffice for the present to lay down the general principle that, in estimating the precision of the 'average price,' regard is to be had not only to the accuracy of the particular price-returns (of the same commodity at different places or times) which are combined into the average, but also to the applicability and worth of the mean so formed.

It may happen, as Professor Marshall has lately pointed out, that the simple average (or Arithmetical Mean) of the particular price-returns may be extremely unsuited to the purpose in hand. Thus, in the case which he puts of *strawberries*, the price both in May and July might be 6*d*., but in June 3*d*. per lb. To take 5*d*. as the mean price might be very misleading. An undue weight is given to the particular price-returns for May

[1] *Contemporary Review*, March 1887.

and July by putting each of them on a level with the price prevailing during the strawberry season, the price which appertains to the bulk of the fruit and concerns the majority of the consumers. A similar difficulty applies to *fish*, of which the particular prices which go to form the average may be taken at very different distances from the fisheries, the higher prices, it may be, having an undue influence on the average.

The milder case of this difficulty is where the revision of the standard is performed so frequently that there is not much difference between successive epochs in the distribution of the quantities in time and place. For instance, it might probably be assumed without error that the proportions of the supply of strawberries consumed in the months of May, June, and July respectively are not materially different in two successive years. The proportionate quantity of fish used by different inland towns might similarly be treated as constant for short intervals of time. In this case it appears to us that the difficulty under consideration may be avoided by one of two methods which are or have been employed in the statistics relating to the Imports and Exports of the United Kingdom. One plan is to take not the simple arithmetical mean of the particular price-returns, *e.g.* $\frac{1}{3}\,[6d. + 3d. + 6d.]$, the price of strawberries being $6d.$ in May, $3d.$ in June, and $6d.$ in July; but to *weight* each of these price-returns with the (more or less accurately estimated) corresponding quantity of goods at each price.[1] It was partly upon this principle [2] that the prices entering into the 'computed values' of British Imports and Exports used to be calculated. The prices were taken at London and Liverpool (sometimes Hull), and also the quantities. As the mean price was put the following expression: (Quantity at London × London price + Quantity at Liverpool × Liverpool price), *divided by* (Quantity at London + Quantity at Liverpool).

[1] The proportions might be roughly ascertained by the method of sample, *e.g.*, examining several markets selected at random, in the respective months. Let the proportions thus determined for the months of May, June, and July be, ${}_{,}\alpha$, α, α' (where ${}_{,}\alpha + \alpha + \alpha' = 1$). Or, if we consider two successive years, we shall have two sets of ratios, say, ${}_{,}\alpha_1$, α_1, α'_1, and ${}_{,}\alpha_2$, α_2, α'_2. Let the total quantities in the respective years be A_1 and A_2. And let the prices for May, June, and July be for the first year as before, $6d.$, $3d.$, $6d.$, and for the second year somewhat different, say, $6d. + {}_{,}\Delta$, $3d. + \Delta$, $6d. + \Delta'$. Now, according to the rough and ready mode of computation, the term contributed by strawberries to the numerator of our formula (see above) is $\frac{1}{2}\,(A_1 + A_2) \times [5 + \frac{1}{3}({}_{,}\Delta + \Delta + \Delta')]$. And the corresponding term of the denominator is $\frac{1}{2}\,(A_1 + A_2) \times 5$. Here, ${}_{,}\Delta$ and Δ' are each put on a level with Δ; though the latter variation is far the most important as affecting the bulk of the goods, the majority of the consumers. This error is avoided by using the *weighted* (instead of the simple) mean of the three prices. The term contributed to the numerator of our formula thus becomes $\frac{1}{2}\,(A_1 + A_2) \times [{}_{,}\alpha_2(6d. + {}_{,}\Delta) + \alpha_2(3d. + \Delta) + \alpha'_2(6d. + \Delta')]$ (or some analogous combination, *e.g.*, that which is formed by substituting in the above expression for ${}_{,}\alpha_2$ the mean value $\frac{1}{2}\,({}_{,}\alpha_1 + {}_{,}\alpha_2)$, and making similar substitutions for α_2 and α'_2). For the corresponding term of the denominator put the same expression modified by the omission of the Δ's. It is clear that in the result thus modified ${}_{,}\Delta$ and Δ' play a much more insignificant part than formerly.

A similar contrast makes itself felt when we adopt the second correction suggested in the text. The average price of the first year is now obtained by dividing the total value by the quantity. The total value will consist of an aggregate of terms analogous to (if not identical with) $A_1 \times ({}_{,}\alpha_1 6d. + \alpha_1 3d + \alpha'_1 6d.)$. And this, being divided by A_1, the total quantity gives us the same sort of expression for the average price as before.

[2] As described in a Memorandum by Mr. Messenger, published in the *Parliamentary Papers* for 1865, vol. i. p. 273.

Another remedy analogous in principle, but perhaps more efficacious,[1] as hitherto carried out in practice, is to estimate the average price as is now done in the case of Imports and Exports by dividing the aggregate of declared values by the total quantity.

When, indeed, a considerable interval occurs between the compared epochs, then, with the progress of the arts, in particular the facilities of transport, the quantities of fruit available out of season, of fish supplies to the inland consumer, are likely to be markedly increased. In this case the modifications just suggested are less helpful. We may have to resort to the more drastic treatment pointed to by Professor Marshall. Or perhaps our best course (however bad the best) might be to follow the general rule given by Professor Marshall for the comparison of epochs separated by a wide interval. It being impossible to bring the last year of the series into direct relation with the first, we ought to compare the last year (in respect of the purchasing power of money) with the penultimate year, the penultimate with the antepenultimate, and so on. In this case the remedies above suggested would be efficacious. To consider the treatment appropriate to each species of goods will be no small part of our next year's task.

Of auxiliary standards the number is unlimited. We distinguish *six* which appear to be particularly important; without attempting to arrange them in an order of merit. (1) One is based upon the larger wholesale commodities, whether imported or manufactured at home. The type of this species is the index number calculated by Mr. Palgrave in the memorandum contributed by him to the 'Third Report on Industrial Depression.' The method adopted by him of *weighting*, or assigning importance to, the given price-variations, seems sufficiently accurate for the purpose in hand; and, being less laborious, may be preferred to the slightly more correct procedure which we have proposed for the principal standard.

Agreeable also to the character of an auxiliary standard is his summary decision of the knotty question, what goods ought to be excluded in order that the same materials should not be counted twice (*e.g.*, indigo, as imported raw, and as worked up with cotton).

This index-number is useful as enabling us, given the increase of value, to estimate the increase in quantity of the class of commodities under consideration. Again, such index-numbers, especially when disposed in a chronological series, assist us in conjecturing the future course of general wholesale prices.

(2) Similar remarks apply to Mr. Giffen's calculation of Index-numbers for Imports and Exports respectively. These measurements, owing to the number of items on which they are built, have a greater precision than that which is founded on only twenty-two articles. We may say, perhaps, that, as indices of the course of prices in general, the standard constituted by Imports and Exports is rather more important to the world than that which is based upon general wholesale commodities to England.

(3) A third very important Index is that which has recently been

[1] The computed prices were based only on *samples* (as described in the Memorandum above referred to). But this disadvantage, as contrasted with the method of total values, may be partly compensated by the inaccuracy which attaches to declarations of value (see Giffen, *Essays in Finance*, series 2, essay 6; and Bourne, *Trade, Food, and Population*, first paper.

proposed by Professor Nicholson.[1] This standard—divested of certain incidents which seem to some of us not essential—may be defined by substituting, in what we have described as the main standard, for 'quantities of finished products consumed per unit of time' the 'quantity existing' of all commodities whatever. The means of roughly evaluating this measure are supplied by Mr. Giffen's paper on 'Recent Accumulations.' This species of index is indispensable in deducing the increase in the quantity of accumulated wealth from the increase in its total value. Besides other general uses, this computation is specially adapted to the construction of a so-called 'Tabular Standard' for deferred payments. For the scaling of certain kinds of debts this index-number might be required.

(4) Another important special index-number is afforded by the budgets of the average working man and his family, representing the consumption of a large mass of the population. However, it is rather with reference to other countries than England[2] that this estimate can be included under the 'practical' category of computations already performed.

(5) Again, there are those of us who think that a special prominence should be given to an index denoting the increase (or decrease) of general wages. Wages certainly constitute a large part of the expenditure (in the way of production, however, rather than of consumption) of an important class, namely, employers (*entrepreneurs*). Wages constitute the income of the majority, and the question (which more particularly concerns us), How far money will go for any class? is with difficulty detached from the question, How much money have they to lay out? In fine, the rate of general wages is an indispensable datum for the inferential estimation (in the absence of a direct measurement) of the values of many finished products which enter into our principal standard.

(6) The results of the last computation (perhaps, also, of the last but one) may be employed to calculate approximately an index-number which, if it could be calculated precisely, might claim to be the principal standard. This latent right appertains to the standard which is based upon the purchases of the average consumer. As here conceived, this index-number differs from that which we have defined as the principal standard chiefly in carrying out more logically the idea which dominates both calculations. The formula of the auxiliary standard is, perhaps, more theoretically correct, though the numerical data entering into the formula may be less accurately ascertainable. The data are now to be exclusively retail transactions, the prices (in the absence of exact statistics) being estimated inferentially from the rate of wages or otherwise. A greater number of commodities, in fact all objects of consumption, instead of only the more characteristic and important, shall now figure as items. In particular there should be included, as forming part of the average consumer's expenditure, residential rent, and the remuneration of professional assistance and domestic service.

This index-number is at a disadvantage as compared with most of the others, in that the required data are furnished by more or less conjectural estimates. On the other hand, it has an advantage, as compared with all the others or all except the fourth, in that the object which it purports to measure is the object most important to measure, the value-in-use of money. As compared with the fourth auxiliary index-number, the sixth has the advantage of relating to the whole community. But there is

[1] *Journal of the Statistical Society*, March 1887.

[2] See *Massachusetts Labour Reports* for 1884; and E Young's *Labour*.

the disadvantage that this national type cannot accurately express the requirements of the individuals represented. The norm which is based on the average consumption of a homogeneous class much more faithfully represents the individuals of that class.

The Committee have also to state that they have had numerous meetings, and have prepared various notes and papers. Among these they would specially refer to a Memorandum by Mr. Edgeworth dealing with the whole subject; which they recommend should be printed in the Proceedings of the Association.

In the course of the proceedings the Committee invited Mr. Giffen to co-operate with them.

Mr. Giffen has placed the Committee in connection with the International Statistical Institute. At the meeting of the Institute, held at Rome in April 1887, there was appointed an *International Committee on Standards of Value*, and Mr. Giffen was nominated as the representative of England. Mr. Giffen desires that he should be assisted in this work by this Committee of the British Association for the Advancement of Science.

To this end, and in view of the difficulty and complexity of the subjects involved, the Committee would recommend that they should be reappointed (with the addition of Mr. Giffen) to report at the next meeting of the Association.

MEMORANDUM BY THE SECRETARY.

INTRODUCTORY SYNOPSIS.

The object of this paper is to define the meaning, and measure the magnitude, of variations in the value of money. It is supposed that the prices of commodities (including services), and also the quantities purchased, at two epochs are given. It is required to combine these data into a formula representing the appreciation or depreciation of money.

It will appear that beneath the apparent unity of a single question there is discoverable, upon a close view, a plurality of distinct problems. Many different branches have been traced, and the number might be largely increased if every bifurcation were followed out to its logical end. But it is not to be supposed that the innumerable ramifications which a formal logic might be able to distinguish would all repay cultivation. The most rigorous analysis may be content with a dozen distinct cases; and for the purpose of an introductory summary these may be reduced under a still smaller number of headings.

To one taking a general view of the subject there stand out four main types, four modes of measurement distinct in idea and definition, though occasionally coincident in practice. The *first* sort of measure is based upon the change in the prices of finished products, the object being to find, or rather show how to find at any future time, a ratio or *Unit* such that the creditor in the future receiving as many Units as he at present receives pounds may derive as much advantage in the way of consumption then as now. The *second* sort of measure is based upon all the articles which trade deals with, the object being to find a Unit such that the debtor in the future, paying as many Units as at present pounds, may not be more hampered in his business then than now. A *third* inquiry is, What is the measure of that appreciation which it is the object of bimetallism and similar projects to correct? The *fourth* sort of measure is required not so much for any particular practical object as for

the more general purposes of monetary science, to interpret the past and forecast the future.

Let us add a few words on each of these methods separately, to explain more clearly either the means adopted or the end proposed, or how far those means are conducive to that end.

(1) The general principle of the first method may be embodied in slightly different rules, of which the following two may claim to be the best. (α) In order to ascertain the change in the value of money between two epochs, find the national[1] expenditure per head upon finished products or articles of consumption (including unproductive services) at each epoch. The ratio of the new to the old expenditure is the required measure of depreciation, or Unit. Otherwise (β) thus (the general principle being interpreted somewhat differently): Find the quantities of each article consumed at the two epochs, and take the mean of each couple. Multiply each of these mean items by the old price of the corresponding article and add together these amounts. Proceed similarly with the new prices. The ratio of the latter sum to the former is the required Unit. There are other formulæ, in all more than half a dozen. But there is not much to choose among them. And the exercise of a choice may exceed the powers and province of the writer.[2]

The advantages of rendering money a steady measure of value-in-use would be considerable wherever there may be violent fluctuations of general retail prices.[3] Such oscillation in the purchasing power of money intensifies the ups and downs of Fortune—so trying both to the sentient and the moral nature of man. The disturbance superadded by a bad currency might be annulled by a corrected standard. The honest labourer would not be cheated of his reward by miscalculations of the value of currency. Those who had laid out their lives upon the faith of a fixed income would not be disappointed of their just hopes. The provision for the widow and the orphan would be more secure. The endowments of learning would preserve that constancy of competence which is favourable to the cultivation of the liberal arts.

These great advantages seem capable of being largely realised. For it is shown by statistics, such as those of Engel[4] and the Massachusetts Labour Reports,[5] that there is considerable constancy in the budgets of family expenditure. Thus in Massachusetts in 1885 the average workman spent out of 100 dollars 29·5 upon groceries, 19·7 upon provisions, 4·3 upon fuel, and so on. Suppose a Unit or corrected dollar continually equivalent to the amounts of groceries, provisions, fuel, &c., which in 1885 were respectively purchased for ·295, ·197, and ·043. There is reason to believe that such a Unit would afford a tolerably constant sum of satisfaction to the Massachusetts working family. But we cannot expect an equally perfect measure, when we construct a Unit, not for a class, but a nation.[6]

[1] See below, p. 272; and p. 262, note 3.

[2] To choose between the first of the rules just given and the second is beyond the scope of this paper (see below, p. 259).

[3] The advantages of a 'Tabular Standard of Value' have been pointed out by many writers. See Jevons, *Currency and Finance*, p. 122, and the references given in the note.

[4] *Volkswirthschaftliche Zeitfrage*, Heft 24. *Inst. Natl. de Statistique*, N. 5.

[5] For 1885. See also Young, *Labor in Europe and America*.

[6] Professor Foxwell writes: 'I think it would also for many purposes be extremely convenient to have an index-number, or numbers, indicating the altered

(2) The desirability of prescribing separately for different interests is even more strongly brought before us when we consider the second of the methods above defined. It purports to be a *sliding scale* for general use, adapted to all trades. But what fits all indiscriminately cannot fit many exactly. We may say of such a project what Steuart says of a certain 'ideal standard,' that it is 'acting like the tyrant who adjusted every man's length to that of his own bed, cutting from the length of those who were taller than himself, and racking and stretching the limbs of such as he found to be of a lower stature.' It would not be unreasonable, however, to construct beds of different sizes, adapted to the average height of markedly different classes of persons, say little boys and men. Similarly, when average prices have largely varied, a scale sliding with the average variation, however imperfectly fitted to particular trades, may be suitable to industry as a whole. The illustration shows the spirit in which our calculation should be performed. What should we think of an upholsterer who, having to construct different types of bed, should invoke the aid of the British Association Anthropometric Committee nicely to determine *l'homme moyen* for different ages? The labours of that committee would not be more misspent than ours, if we attempted in framing a universal sliding scale to determine the ideally best *weight* for each item entering into the combination. Almost any combination of the more important articles of trade is likely to be equally imperfect and equally serviceable. See p. 274.

The advantages aimed at by this method may be presented under two aspects. That steady secular decline of prices which, according to many eminent writers, is a cause of the depression of trade, might be corrected. The advantages offered by bimetallists would be attained. There might be also another benefit which not even bimetallists venture to promise. The sudden violent oscillations in general prices, occasioned by the derangement of credit, would be arrested. For, as the supply of money to meet debts became deficient, the demand for money to meet debts would proportionately dwindle; the amount of debts in 'standard' currency inversely varying with the value of metallic money.[1] The hunger for gold would be less felt just as the means of satisfying it were less abundant. Heretofore a contraction of currency has acted like an atmospheric depression in the physical world. The drain and rush of the medium has produced a storm. But in the new commercial Cosmos, equilibrium between debts and currency being continually preserved, the stormy winds of Panic will have ceased to blow. Hitherto the relation between liabilities and currency has been that of a continent to the ever-changing level of the sea. Each ampler tidal wave has rendered harbours unserviceable, and dislocated trade, and strewn the shore with wrecks. But the latest invention of science is a sort of *floating dock*, which shall rise with the flood and sink with the ebb, so that the argosies of commerce may be safely landed, whatever the level of the transporting medium.

purchasing power of selected amounts of consumers' incomes, estimated in the corrected standard. I mean that having first determined, by our principal standard, the corrected value of 1*l.* for the given year, we should then find the alteration in the purchasing power of the new standard 1*l.* for different incomes: *e.g.*, for incomes of 50*l.*, 100*l.*, 200*l.*, 500*l.*, 1,000*l.*, and 10,000*l.*'

[1] This action is well exemplified in the plan proposed by William Cross, that the standard should vary *per saltum*; a correction being made as often, say, as money was appreciated (or depreciated) by 3 per cent.

These are fascinating images, ideal possibilities, which the sober thinker may entertain while he is conscious how remote and uncertain is the realisation; how numerous the difficulties and objections. Perhaps the new organisation of the money market would develop new varieties of roguery. Certainly complications would arise between liabilities to the foreigner expressed in gold, and engagements with the home trader expressed in the adjusted currency. It is alleged, too, that the business of banking would be impeded. In fine, the common sense of business men appears opposed to the scheme; and, on the question what is at present practicable and what not, the opinion of practical men, even unsupported by reasons, is conclusive.

(3) The third inquiry is, What is the appreciation (or depreciation) which it is the object of bimetallism and similar projects to correct? What is that mean (or function) of prices which the bimetallist would desire to keep constant? Of course, if prices varied all in much the same ratio, like the lengths of shadows with the advancing day, the answer would be very simple. That ratio is the required measure. But suppose that one large category of prices is pretty uniformly elevated, while another is *en bloc* depressed; we desiderate a measure which, like the two preceding, may be independent of the particular hypothesis that there has been a uniform average price-variation all over the field of industry. Upon reflection it will be found that the required measure can be none other than one of the two preceding or a cross between them. The bimetallist may be satisfied that his object is attained when the (above-defined) 'Unit' is unity. See pp. 278, 279.

It is to be observed that the Unit required for this purpose cannot be restricted to a particular geographical or industrial area. Rather the averaging must be extended over the whole system of countries in monetary communication—that is, over the greater part of the civilised and uncivilised world.

(4) When we consider the next type, the fourth definition of our problem, there once more is pressed upon us the expediency of limiting the area of markets over which our measurement is to extend. It may be doubted whether a standard based upon the variation of all prices indiscriminately would—abstracted from some definite particular purpose such as those contemplated in the preceding paragraphs—be of much scientific use. It would be like taking the mean barometric pressure over a large continent. It is more useful to observe the variation of pressure at particular stations, in order to predict what changes will be propagated to neighbouring regions, what storms are coming. Suppose, for the sake of illustration, that at any station the reading of a single barometer was not sufficient to give the true pressure; that each instrument was liable to a proper disturbance over and above the general atmospheric change. The heat or cold, for example, of different situations might cause a misleading expansion or contraction of the mercury. On such a supposition it might be proper, in order to measure the pressure at any station, to take a mean between the readings of several barometers. Upon well-known hydrostatical principles, no particular importance, other things being equal, would attach to the reading of the barometer which contained a particularly large mass of mercury.

These conceptions appear appropriate to our problem. We should demarcate a certain region of industry, and estimate in terms of that special group of articles an index-number indicative of changes which are

likely to become general. The zone of observation most suitable to our purpose would probably be as it were the coast-line of trade, those articles of world-commerce which are most sensitive to changes propagated from abroad. In taking such a mean of observations the 'weights' are not necessarily proportioned to the masses of commodity. *Primâ facie* and in the abstract pepper may afford as good an index as cotton. (See pp. 281, 282.) The writer has given rules for taking the mean of these observations. But he is aware how difficult it is to define the proper zones; how hardly susceptible of perfection is the science of monetary meteorology.

Contemplating all these types we discern a property common to most of them, the desirability of treating separately selected interests, rather than operating upon all commodities indiscriminately. To construct such partial measures does not seem to be the business of this Committee, or at least this Memorandum. We may, however, hope that our theoretical diagnosis of different purposes may be of use to those who undertake the more practical task of prescribing for different interests.

SECTION I.

Description and Division of the Problem.

The business of this Committee is to measure a fact, not to speculate about its causes or consequences. Should a fall in the value of money have occurred we need not trace that phenomenon to its sources. Whether it takes its rise on the side of the precious metals or of commodities—whether, in Dr. Johnson's phrase, it is the pence that are few or the eggs that are many—it is not our part to determine. The consequences of the change are equally outside our province. It is open to us to hold with Hume that, when prices are rising owing to the influx of money, 'everything takes a new face; labour and industry gain life.' With General Walker we may predicate the converse attributes of falling prices. Or we may accept Professor Marshall's [1] qualified, or Mill's [2] negative, statement of those effects. We have to leave speculation and apply ourselves to measurement.

But, while we are not called upon to decide such controverted questions, we cannot be as indifferent to the decision as might at first sight have appeared. For it is only in the simpler kinds of measurement that the metretic art can be entirely divorced from theory about its subject-matter. To measure the height of a man we do not require a knowledge of anthropology. We may even ascertain the mean stature of a nation without much special knowledge. But difficulties arise when we have to do not with one attribute, such as *height*, but with two (or more) attributes: for instance, the masses and velocities of a system of bodies. Take the simple case of a number of heavy particles at rest, and suppose that different velocities are imparted to the different particles between two given epochs. It would not be very easy for one coming fresh to the study of mechanics so to define his confused general idea of the *change of motion* which had occurred as to be able to express it in terms of the data: namely, the masses, say M_1, M_2, &c., M_n, and the imparted velocities (which, in order to minimise difficulties, we will suppose all in the same direction) V_1, V_2, &c., V_n. It is plausible to say that the problem is

[1] *Third Report on Industrial Depression*, Appendix C, vol. ii. p. 422, column b.
[2] *Pol. Econ.* Book III. chap. xiii. s. 4.

purely statistical, that we seek a merely objective result. The difficulty is that any combination—at least, any symmetrical combination—of the data is in a sense objective. We must call in mechanical science to determine what combinations are worth forming and what are insignificant. Consider the two combinations

$$M_1 V_1^2 + M_2 V_2^2 + \&c. + M_n V_n^2 \text{ and } M_1^2 V_1 + M_2^2 V_2 + \&c. + M_n^2 V_n.$$

Primâ facie, these are both equally 'objective,' and they seem equally simple. But while the former (the expression of energy) constitutes a spell for opening all the secret chambers of Nature, the latter could only be significant on some very peculiar hypothesis, for some very out-of-the-way purpose.

Similarly, in the problem before us we have to combine two sets of data, the prices of different articles and the quantities thereof. Indeed, our problem is rather more complicated. We may have to take account of a third attribute, the *quality* or species of wares; to consider, for instance, whether the price and quantity of labour or of materials shall enter *pari passu* and symmetrically into that combination of our data which we desiderate.

In order to discover the principle on which this combination is to be effected, we may be led into the most perplexed regions of monetary science. We are brought against the question, What is the relation between the amount of money in a country and the general scale of prices? —the question which has been called by a distinguished authority [1] 'one upon which the most contradictory opinions have been expressed by economists of reputation.' And even where there are no fundamental differences of theory, yet practice may vary according to the practical end in view. Some may aim at the construction of a tabular standard, adapted only to contracts extending over a long period of time; others may desiderate a more flexible standard, which may mitigate the effects not only of the secular, but also of the more [2] transient variations in the value of money; others may seek only an index of the future course of prices—a sort of monetary barometer.

There are therefore many methods—not one method—of 'measuring and ascertaining variations in the value of money.' The path which we have to investigate has many bifurcations. To decide at each turn which is the right direction is either impossible, or at least presumptuous. It is impossible when both ways are right, directed to different but equally legitimate ends. And, even where there must be a right and wrong, it is not becoming here to pronounce upon points controverted by high authorities. The course adopted is to trace separately the alternative paths, indicating the difference without expressing a preference.

In this memorandum it is proposed to distinguish the various cases of the general problem, and to construct the formula appropriate to each case. The numerical determination of the quantities which enter into the formulæ—both the compilation of the proper figures from explicit statistics, and, where these are wanting, the more speculative arts of inferring unknown prices and amounts from imperfect data and indirect indications—these parts of the subject are not treated by the present writer. They may be considered in a future Report of the Committee and in separate memoranda contributed by other members.

[1] General Walker in his *Money*.

[2] As Professor Marshall hopes; *Contemporary Review* March 1887.

PROBLEM OF MEASURING CHANGE IN THE VALUE OF MONEY.

- A. Solution irrespective of hypothesis as to the cause of the data.
  - B. *Quæsitum*, the construction of a standard for deferred payments.
    - C. Standard required to be constantly equivalent to the same quantity of valuables.
      - D. Constituents of the standard corresponding to the items of national consumption.
      - d. Constituents of the standard determined on some other basis than national consumption
    - c. Standard required to vary on the principle of a sliding scale.
      - D. Constituents of the standard corresponding to the items of national consumption.
        - E. The standard varying with national income.
        - e. The standard varying with national capital
      - d. The standard determined on some basis other than national consumption.
  - b. *Quæsitum* other than the construction of a standard for deferred payments.
- a. Solution based upon an hypothesis as to the cause of the data.
  - F. Irrespective of quantities of commodities.
  - f. Account being taken of quantities of commodities.

The delicate subdivisions of the subject are exhibited in the annexed diagram by means of a regular *logical tree* [1] In examining this tree of knowledge we shall give priority to the branches on the left. As soon as we have reached the definition of each ultimate species we shall add its properties—the treatment adapted to that particular case. We shall not only trace out the form of each branch, but also gather the fruit at its extremity, before we go on to the branch nearest on the right.

The whole subject is first divided according as the method adopted is (A) irrespective of any hypothesis as to the cause of the price movements or (a) is based on some such theory. Deferring the treatment of the latter case (a) we proceed to divide the former according as (A B) the practical purpose in view is to construct a standard or 'Unit' for deferred payments, or (A b) some other purpose. Postponing the latter case, we may complete the definition of the former by explaining that the Unit (a term borrowed from Professor Marshall's recent article in the 'Contemporary Review'), as used here in a general sense, means a sum of money estimated to be equivalent at present (or at some future time) to what a Unit of money, say a pound, was worth at some past time: in such wise that it may be just or expedient for debtors to pay, and creditors to receive, as many Units now (and from time to time) as they contracted to pay and receive pounds at the initial epoch. The general idea of a Unit may be specialised according as it is required that (A B C) the Unit should constantly be equivalent to the same quantity of valuables, or (A B c) that it should not represent a constant purchasing power, but one varying with the means of debtors, after the manner of a *sliding scale*. Lastly the kinds and quantities of the valuables entering into the Unit may either (A B C D) correspond to the items of national consumption, or (A B C d) may be selected on some other principle. In this arrangement priority does not import any preference.

SECTION II.

Determination of a Standard for Deferred Payments; based upon the items of national consumption; calculated to afford to the consumer a constant value-in-use; no hypothesis being made as to the causes of the change in prices. (A B C D.)

According to this arrangement, the first case for which we have to prescribe is where, apart from any hypothesis as to the cause of the movement of prices, we want to construct a Unit adapted to deferred payments, and where it is required that the Unit should be constantly equivalent to the same amount of valuables, the kinds and proportions of the valuables corresponding to the items of the national expenditure. Upon reflection it will be found that the last attribute involves, or is deduced from, some such condition as the following—that the *advantage* which an average person derives from the expenditure of a Unit should be constant.[2]

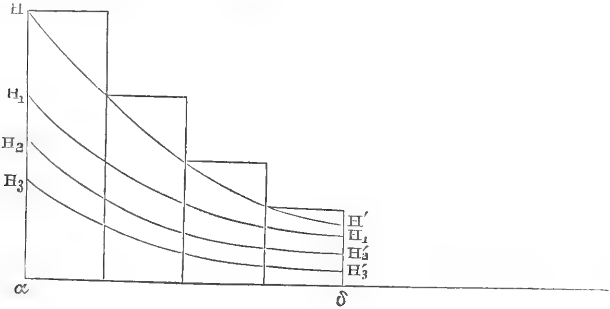
[1] As logical and genealogical trees for the most part, like the trees in the poet Parnell's *Hermit*, 'depending grow,' it may be as well to point out to the reader that our tree, like those cultivated by some of the earlier logicians, is trained *upwards*.

[2] Cf. Horton, *Silver and Gold*, chap. iv. 'In the average annual consumption of provisions . . . we should have at least fixed a definite portion of utility. . . . By enlarging the sphere of consumption on which to base the average . . . we still more nearly attain a measure of the value of Money.'

From this condition, owing to the unequal consumption[1] of different individuals it follows that the precision of our calculation cannot be great. That is to say, we cannot be certain that between considerable limits some other ratio than the one which we have chosen would not be as good as the one which we have chosen.

It may be worth adding that even if we could suppose that all commodities were consumed in the same proportions by all individuals, yet the mere difference in the size of fortunes and of debts would introduce an inaccuracy. To show this let us first suppose that all fortunes would be equal but for the payment of debts;

FIG. 1.



and let us represent the average amounts of commodities consumed by the height of the columns in the annexed diagram, the divisions of the horizontal line being equal. Now suppose a person, from being a consumer of the average amount of each article, becomes debtor to the extent of a certain sum, expressed in *Units*[2] of tabular standard. Theoretically he would retrench something of his expenditure on each article, contracting as it were the *margin of final utility*. He might thus fall back upon the curve H_1H_1' instead of the original boundary. And if his debt increased he might have to fall back upon an interior frontier, the next *isohedone*, as we might call this family of curves. Conversely, in the case of a creditor. Now, in order that our standard should be applicable to debts of various sizes it is virtually assumed that the ratio $HH_1 : H'H_1'$ is the same as $H_1H_2 : H_1'H_2'$, and so on for other columns and curves. But this assumption is without evidence, or rather contrary to evidence. Or, if it be held sufficient that the standard should represent the utility corresponding to the *average* debt, still even for this purpose our method of determining the proportions (by the totals consumed) is arbitrary—*à fortiori* when we admit all kinds of inequalities of fortune and other irregularities. Thus it may plausibly be contended in virtue of the analogies of Fechner's law that, where the total wealth of a people has increased, an equal quantity of utility is represented by a larger quantity of wealth.[3] In this case Method A B c D (explained below) might be the legitimate deduction from the principle on which we here suppose method A B C D to depend.

It is important to realise how loose is the character of the calculation even

[1] Cf. Professor Marshall, *Industrial Conference*.

[2] The term *Unit* is here employed in the sense proposed by Professor Marshall, *Contemporary Review*, March 1887.

[3] The standard defined in this section, the Consumption Standard as it may be called, appears to be particularly appropriate to the case in which National Wealth is regarded as a constant quantity. Otherwise there is apt to arise a divergence between two attributes which we have hitherto assumed to be conjoined, namely, the condition that the Unit should be constantly equivalent to the same quantity of valuables, and that it should afford, on an average at least, the same quantity of value-in-use, the same 'Final Utility.' For, according to the *Law of Diminishing Utility* (expounded by Laplace, Jevons, and others), the same increment of means tends to

under the most favourable conditions. To expend minutious care in determining our weights when our balance is thus rough is nugatory. It is taking care of the pence and leaving the pounds to take care of themselves, a course dictated rather by proverbial than practical wisdom.

It follows from the condition above stated that the frequent resale of an article (such as cotton) forms no reason why it should be counted more than once. Nor should materials, as distinguished from finished products, be counted, or only as representative of finished products. Upon the same principle the price of stipendiary labour [1] (domestic wages and many

afford a smaller increment of advantage when the fortune to which addition (or from which subtraction) is made is ampler. If, then, National Wealth increasing, the average fortune becomes larger, the Unit which is equivalent to the same quantity of things will no longer correspond to the same quantity of advantage. The average scale of living being higher, the same amount of goods will not appear of the same importance to the average consumer. Accordingly, in such a case we must make a choice between the following two conditions for the definition of our Standard or Unit. The first condition is that the Unit should constantly be equivalent to the same quantity of valuables. Or since, agreeably to the views here adopted, quantity of valuables cannot in general be defined irrespective of subjective considerations, it might be more philosophical to lay down as the first condition that the Unit should constantly afford the same quantity of utility; *abstracting the change of National Wealth*, supposing that the fortune of the average consumer remained constant. The alternative condition is that the utility afforded should be constant, that circumstance *not* being abstracted. As a matter of nomenclature, it seems better to restrict the symbol C, the term *Consumption Standard*, to the former definition. The latter arrangement may be regarded as a variety of the genus *sliding-scale*, designated by c.

Dr. Julius Lehr, in the important contribution to our subject made in his *Beiträge zur Statistik der Reise* (Frankfort, 1885), seems to assume the proposition that the utility derived from wealth at both the compared epochs is the same; or at least that the final utility at each epoch is the same, or rather a quantity of the same order. For he takes as the measure of the importance of an article the number of *Genusseinheiten* afforded by its consumption. Now, Dr. Lehr's *Genusseinheit* and Jevons' *Final Utility* are quantities of the same dimension. A hundredweight of diamonds, say, affords so many times more *Genusseinheiten* than a hundredweight of iron, as the Final Utility of the former is greater than the Final Utility of the latter. To determine the number of *Genusseinheiten* conferred by (the objective unit, *e.g.*, hundredweight, of) each species of article, Dr. Lehr in effect takes the mean of the Final Utilities at each epoch. Now he who takes a mean assumes that the quantities of which he takes a mean are of the same order.

[1] The exclusion of 'services' as distinguished from material commodities has been maintained on the ground that so-called 'unproductive' labourers are paid out of the proceeds of productive industry. The money which we expend on singers and dancers finds its way to butchers and bakers. To include in the National Inventory the outlay on Singing and Dancing as well as the total expenditure on Bread and Meat is therefore to count the same portion of wealth twice over. And no doubt this remark is relevant, where the object is to measure the quantity of Wealth defined as something *material*. But for the present purpose, would it not be theoretically as reasonable to omit Bread and Meat and base our standard exclusively upon the price of theatrical entertainments and such like, upon the ground that what we pay to the butcher and baker finds its way to the Music Halls which they frequent? 'No,' it may be replied, 'for a good part of their income must be expended on material necessities. Well, but by parity a good part of the wages of 'unproductive' labour may be expended on immaterial utilities. What is earned by teaching literature may be spent in tickets for the opera. Theoretically it is as arbitrary to altogether exclude immaterial utilities, as it would be to include nothing but them. The difference between the two errors is only one of degree and practical importance. As a matter of fact in the existing world, of the two defective methods the less imperfect is that which includes material, and excludes immaterial, utilities. But the converse might be true in some happy island, where the material necessities of life were obtained almost for nothing, and the principal monetary transactions were constituted by the exchange of mutual services.

professional payments) enters in as an independent item; but the price of industrial labour (ordinary wages) only as representative, and in the absence, of the finished products.

In constructing the formula for combining the quantities and prices thus defined, we may first distinguish the abstract and ideally simple case in which exactly the same quantity of each article is consumed at the two epochs. In this case the method of procedure is that indicated by Professor Sidgwick in his *Political Economy* (Book I. chap. ii. s. 3): 'Summing up the amounts of money paid for the things consumed [1] at the old and the new prices respectively,' and [to find the value of the Unit at the later epoch] dividing the latter sum by the former.

A difficulty arises when we introduce the concrete circumstance that the quantities consumed at the two epochs are not the same. We might distinguish two grades of this deflection from the abstract ideal: (I) where the interval of time between two revisions being very small the variations in the amounts consumed are slight, *differentials*, we might call them; and (II) *integral* or considerable changes which occur in the course of a long interval of time.

1. The method of procedure in the first case may thus be symbolised: Let α, β, γ, &c., be the quantities of commodities consumed [1] at the initial epoch, and α', β', γ', &c., at a subsequent epoch; it is assumed that $\frac{\alpha'}{\alpha} = \frac{\beta'}{\beta} = \frac{\gamma'}{\gamma} = \&c. = 1$ nearly. And similarly for a second subsequent epoch $\frac{\alpha''}{\alpha} = \frac{\beta''}{\beta} = 1$ nearly. Upon these assumptions several methods of determining the Unit present themselves. Let us designate the prices at the initial epoch by $p_\alpha\ p_\beta\ p_\gamma$, &c., and at a subsequent epoch $p_\alpha'\ p_\beta'\ p_\gamma'$, &c. Then,

(1) We may take the type which first presents itself upon Professor Sidgwick's view of the problem, viz.—

$$\frac{\alpha p'_\alpha + \beta p'_\beta + \&c.}{\alpha p_\alpha + \beta p_\beta + \&c.}.$$

This method is (in effect) adopted by Mr. Sauerbeck for years earlier than 1866–77 ('Journ. Stat. Soc.' 1866, pp. 595–613).

The method is also exemplified by Mr. Giffen's retrospective estimate of the change in the value of money between 1873 (and 1883), and *earlier* years (Report on Prices of Exports and Imports, 1885, Table V.).

(2) The next type, also given by Professor Sidgwick,[2] is the converse of the first, viz.—

$$\frac{\alpha' p'_\alpha + \beta' p'_\beta + \&c.}{\alpha' p_\alpha + \beta' p_\beta + \&c.}.$$

This method is exemplified by Mr. Giffen in his Table IV. (Reports 1881, 1885), by Mr. Mulhall, and by Mr. Sauerbeck (for years after period 1867–77), ('Journ. Stat. Soc.' 1886, p. 595).

[1] Agreeably to this definition the prices on which the Consumption Standard is based should theoretically be the prices paid by consumers—retail prices. For *this* purpose wholesale prices are to be employed only in the absence of the proper statistics, as an index of prices paid for the finished products—a very imperfect index, as Dr. Scharling, in his excellent paper on retail prices, and other authorities, have shown.

[2] See the passage above referred to.

(3) The third type is a mean between the first two, viz.—

$$\frac{1}{2}\,\frac{\alpha p'_{\alpha} + \beta p'_{\beta} + \&c.}{\alpha p_{\alpha} + \beta p_{\beta} + \&c.} + \frac{1}{2}\,\frac{\alpha' p'_{\alpha} + \beta' p'_{\beta}}{\alpha' p_{\alpha} + \beta' p_{\beta} + \&c.}.$$

Professor Sidgwick has suggested and remarked upon this procedure in a note. It has been noticed also by Drobisch.

(4) The next type is also a mean :—

$$\frac{\frac{1}{2}(\alpha+\alpha')\times p'_{\alpha}+\frac{1}{2}(\beta+\beta')\,p'_{\beta}+\&c.}{\frac{1}{2}(\alpha+\alpha')\,p_{\alpha}+\frac{1}{2}(\beta+\beta')\,p_{\beta}+\&c.}$$

suggested independently by Professor Marshall and the present writer.

(5) The next type is one adopted by Mr. Palgrave :—

$$\frac{\alpha' p'_{\alpha}\times\dfrac{p'_{\alpha}}{p_{\alpha}}+\beta' p'_{\beta}\times\dfrac{p'_{\beta}}{p_{\beta}}+\&c.}{\alpha' p'_{\alpha}+\beta' p'_{\alpha}+\&c.}.$$

(6) The sixth type is that which Mr. Giffen has employed in his Table III. Put ${}_{,}\alpha$ and ${}_{,}p_{\alpha}$ for the quantity and price of the first commodity in 1875 (or other year selected as representative). Then for the increase in the value of money in the year whose symbols are α', p'_{α}, as compared with year α, p_{α}, write :—

$$\frac{{}_{,}\alpha\,{}_{,}p_{\alpha}\times\dfrac{p'_{\alpha}-p_{\alpha}}{p_{\alpha}}+{}_{,}\beta\,{}_{,}p_{\alpha}\times\dfrac{p'_{\beta}-p_{\beta}}{p_{\beta}}}{{}_{,}\alpha\,{}_{,}p_{\alpha}+{}_{,}\beta\,{}_{,}p_{\beta}+\&c.}.$$

The expression for what we have called the Unit is found by adding *unity* to the above (substituting $\dfrac{p'_{\alpha}}{p_{\alpha}}$ for $\dfrac{p'_{\alpha}-p_{\alpha}}{p_{\alpha}}$).

(7) Next we may place the formula of Drobisch, of which the principle is to compare the price at different epochs of an objective unit, such as a hundredweight, supposed to be made up of all sorts of articles in the proportion in which they enter into national consumption. In our notation the formula (for what is here called the unit) becomes

$$\frac{\alpha' p'_{\alpha} + \beta' p'_{\beta} + \&c.}{\alpha' + \beta' + \&c.} \div \frac{\alpha p_{\alpha} + \beta p_{\beta} + \&c.}{\alpha + \beta + \&c.}.$$

(8) Last, but not least, either in respect of bulk or of theoretic weight, occurs the formula of Dr. Julius Lehr (referred to above, p. 263), of which the principle is to compare the price at different epochs of a *pleasure-unit*, or unit of final utility. The formula may be thus conveyed in our notation :—The mean 'Genusseinheit,' or *final utility*, of the first commodity is $\dfrac{\alpha+\alpha'}{\alpha p_{\alpha}+\alpha' p'_{\alpha}}$. Of such units these came into consumption, α at the first epoch, and α' at the second. Now sum up all the *Genusseinheiten* for all the commodities which came into consumption at the initial epoch, and divide the national expenditure ($\alpha p_{\alpha} + \beta p_{\beta} + \&c.$) by the sum of *Genusseinheiten*. Thus you have the average price at the initial epoch of a *Genusseinheit*; say P_1. Similarly determine P_2 for the posterior epoch. Then $P_2 \div P_1$ is the required unit.[1]

[1] With regard to the formula proposed by Dr. Lehr, the present writer agrees with the criticism expressed by Professor Lexis in a recent number of Conrad's *Jahrbuch*.

Of these methods it may be remarked that the first four seem to have an advantage over the remaining two, in that the former make no assumption as to the extent of the change of price, while the latter proceed on the supposition that those changes are small. The fifth method seems to assume that we may write for p'_α $p_\alpha(1+\Delta'_\alpha)$, where the second powers of Δ'_α are negligible. And similarly in the sixth method we must be allowed to write for ${}_{\prime}\alpha_{\prime}p_\alpha$ ${}_{\prime}\alpha p_\alpha(1+{}_{\prime}\Delta_\alpha)$, where ${}_{\prime}\Delta_\alpha \times \Delta'_\alpha$, ${}_{\prime}\Delta_\beta \times \Delta'_\beta$, &c., are negligible. No doubt, when we grant the steadiness of the proportions $\frac{\alpha'}{\alpha}$, $\frac{{}_{\prime}\alpha}{\alpha}$, &c., we can hardly refuse this additional postulate.

The first four methods are all equally good if our fundamental hypothesis is strictly true. Where, as in fact, the hypothesis is only hypothetically true, the third and fourth methods, being of the nature of *means*, are apt to minimise error.

On the whole, the fourth method may appear the best; abstracting the difficulty of obtaining the proper numerical data, which is beyond the scope of this paper.

The seventh method is exposed to the objection (noticed by Dr. Lehr) that services cannot be weighed by hundredweights. Dr. Lehr's own formula is objectionable only on account of its bulkiness. (See above, note to p. 263)

It might be a good plan to take the mean of the numerical results of all the methods that are equally entitled to confidence (? the third, fourth, seventh, eighth, and—in the absence of violent price-variations—the sixth and seventh). We might thus obtain not only a better result, but also the opportunity of forming an opinion upon the *error* incident to the calculation: by how much it is likely, and by how much it is unlikely, that the result should be wide of the mark.

There are some other concrete circumstances which may entail some modifications of the general rule: (1) Unless the interval between the revisions of the units be very short indeed we must suppose that the unit is employed at times when, owing to the movements of prices (since revision), it has ceased to be exact.[1] Ideally it might be best, instead of p'_α, p'_β, &c., present prices, to take for each article the mean of its present price and its prices in the proximate future for all the period that the unit has to function unrevised. But of course we cannot know the future prices, and therefore we must be content with taking present prices (or it may be means of the present and the immediate past) as the best representatives of the ideally preferable *mean*. Now, considering the fluctuations of each price

The received formulæ and Dr. Lehr's formula are equal as touching their theoretical validity; but the former (including our A B c D) have the advantage of practical simplicity.

Dr. Lehr's treatment of the *variables* as distinguished from the formula also calls for remark. His object being to discover how far the power of money to purchase *Genusseinheiten* has varied, it is not quite clear why he should insist on including wages, the wages of ordinary industrial or productive labour as well as of stipendiary services, among the data. Do we not take sufficient account of productive labour when we take account of the finished products? *Either*, but not *both*, these items should figure in the expression of our Unit.

One more remark seems called for in justice to the reader whom our notice of this work may have attracted. He must not be discouraged by the opening paragraphs, which are both extremely obscure and not directly relevant to our present purpose. The general reader is advised to begin at p. 10 ('Der begriff. Durchschnittpreis'), or even at p. 28 ('Das Verfahren zur Ermittelung des Geldpreises,' &c.).

[1] This obvious circumstance is explained at some length by Held in Conrad's *Jahrbuch* for 1871.

between two periods of revision, we see by the theory of errors that the price which fluctuates least is (*cæteris paribus*) the best representative of mean price. And accordingly, in the combination of the different indications of change in the value of money, there is a *primâ facie* presumption that peculiar weight should be assigned to those indications which are peculiarly accurate.

But the validity of this principle turns upon very nice considerations. Where we have several measurements of one and the same thing it is indisputable that more weight attaches to the less fluctuating measures. This is true not only in the case of a real objective measurable, such as the distance between two points, but also where the *quæsitum* is a subjective mean, such as *l'homme moyen*. If, as in a case mentioned by Dr. Baxter,[1] we have two sets of measurements of heights of American citizens, the one executed with the utmost precision, the other rough-and-ready, then, in order to obtain the best value for the mean height of the American man, it would be best to affect those careless measurements with inferior weight.

But it may be otherwise when we are seeking not a single mean, but the sum of two or more. If we have to determine the distance from Dover to York *viâ* London, and we have very good measurements for the first distance, and very bad for the second, the best that we can do, though bad may be the best, is to add together without qualification the two means. So if we have to determine the income of a nation consisting, say, of two classes, upper and lower, for one of which the returns are very accurate, for the other very [2] loose, still the best combination of data which is available is the simple addition of the two estimates.

Yet again, if we have several estimates of such a compound mean as has been supposed, the principle of *weight* may again make its appearance. Suppose that, as Laplace proposes [3] (in the case of birth-rates), it were the practice to ascertain the statistics of 'a great empire' by way of *sample*. Let observations be taken on several villages or districts, consisting each of an upper, middle, and lower class. In combining these observations so as to obtain the mean income for the empire, it would be proper to assign less weight to those localities where the returns were obtained in a more summary fashion, by a less accurate method. Further, although each estimate might not be based upon all the classes in each district, but only on a miscellaneous selection from them, still if we could divide such estimates into two classes, contrasted in respect of accuracy and differentiated by no other attribute, the best method of combination would be a weighted mean.

To apply these principles: (1) if, like Jevons, we content ourselves with taking *samples* of commodities rather than all commodities—a perfectly legitimate procedure, and justified alike by the theory of Laplace and the practice of statisticians, *e.g.*, Jevons in his enumeration of sovereigns—then undoubtedly, the principles of *inverse probability* becoming applicable to this mode of measurement, greater weight should attach to the less fluctuating species of returns. It might indeed be a nice question how much the principle of *quantity* should be cut into by the consideration of fluctuation. Thus, if we took Mr. Giffen's [4] statistics of the variation in the prices of exports and imports as a sample (or part of one) of the change in the purchasing power of money, cotton perhaps, on account of its unique importance in respect of quantity, stands out by itself, and ought to receive full weight. But if we have several articles of about the same importance in respect of quantity but differing in fluctuation, a higher combination-weight should be assigned to the less fluctuating mass of value.

(2) A similar principle should govern our procedure, if we had to base our calculation upon returns relating not to the whole population, but only to specimens thereof. Suppose, for instance, it was sought to determine the change in the value of money in China, and that statistics could only be obtained for certain representative localities. If we make a complete enumeration of com-

[1] United States Sanitary Commission.

[2] Supposing, of course, no *animus mensurandi* or *constant error* in one direction such as that of underrating income.

[3] *Théorie Analytique.*

[4] *Parl. Papers,* 1881–85.

modities we ought to take account of all articles, without regarding whether they are consumed in the same proportions, or in different proportions by different persons. But if we proceed by way of sample, then we ought to assign special weight to those articles which, as Engel's law and the American labour statistics have established, are consumed in nearly equal proportions by each household throughout a large class of the community. Less weight should attach to those articles, the 'sundries' of the statistics referred to, which appear more fitfully in the household budgets. How far in England we have to proceed by way of samples afforded by certain markets and certain commodities is a question not to be decided in this memorandum. The difference upon which these distinctions turn is that which the writer, in treating of the theory of errors, has drawn between simple induction and inverse probability (see *Observations and Statistics*, 'Camb. Phil. Trans.' 1885).

(3) A more obvious ground of selection is that some articles (however large their money value) interest only a comparatively few (rich) persons. Accordingly, in constructing a standard adapted to the general requirements of the community, we ought upon utilitarian principles to treat the variations in the price of that class of articles as of comparatively little account.[1]

It may be doubted whether the practical worth of these subordinate modifications corresponds to their theoretic interest. For to assign less importance to some of the data on the ground of a deficiency of weight which is not susceptible of numerical evaluation is a practice which, though countenanced by the example of physicists in their reduction of observations, is apt to diminish confidence in sociological calculations. For the sake of a little additional accuracy it may not be worth while incurring the suspicion of cookery:—

Denique sit quidvis, simplex dumtaxat et unum.

2. We come now to the case where, the interval between the compared epochs being considerable, the quantities consumed at the two epochs are materially different, and the ratio of the quantity consumed at one epoch to the quantity consumed at the other is no longer even approximately the same for the different commodities. The difficulties presented by this case, which seemed to defy science, have been triumphed over by Professor Marshall.[2] The incommensurable proportions of the dissimilar expenditures he manages to compare by means of a series of the intercalated intermediate forms presented by the changing national inventory. Equating each term of this series to its

[1] Another modification which might be suggested is that less weight should be attached to those commodities of which the price-variations affect the general public and a particular class in different senses—a fall, for instance, benefiting the consumer, but ruining the producer. It will be found, however, a difficult and endless task to carry out this principle. For what commodities would be excepted from it? Imports perhaps, in so far as it is the foreign producer chiefly who is damaged by the fall and benefited by the rise of those prices. But with regard to the home industries, in order that the interest of the producer and the consumer should vary in opposite directions, we must suppose an equilibrium of profits to be transmitted from trade to trade, according to Ricardian principles, with a rapidity that is not supposable.

But not only is the working of the proposed principle difficult, but also it is incorrect; *here*, in this section, where our object is that the unit should afford a constant quantity of valuables to the average consumer, without reference to the number of units which the different classes of consumers have to spend (see below, p. 272, note 2). To tamper with certain items of expenditure, such as wages of Domestic Service, on the ground that these transactions belong to *distribution*, as distinguished from *exchange*, is virtually to introduce the principle of the *sliding scale*, to substitute the attribute c for C.

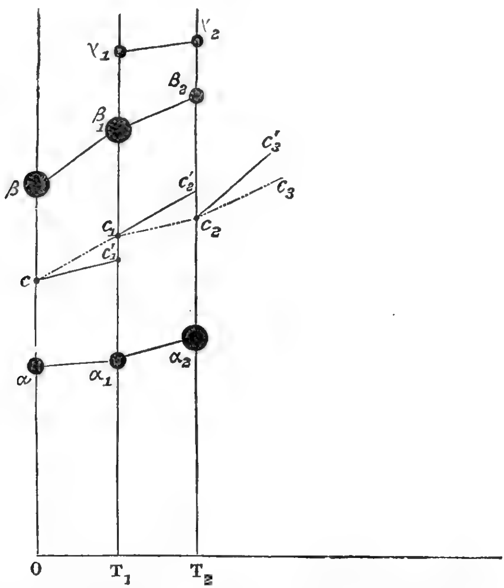
The exclusion of 'unproductive' labour has been maintained on other grounds considered in note to p. 263.

[2] *Contemporary Review*, March 1887.

predecessor and its successor, he brings the first term into relation with the last term. Though the final and initial shapes of the *Unit* cannot even approximately be superposed, yet its content of utility is preserved constant. It is true that at each step of this process some deviation may occur. At each act of weighing something may fall out of the balance. But something may fall in also. And thus, in the absence of a constant bias towards error in one direction, there is reason to believe that—except for very long deferred payments—the result will be as accurate as that which is attainable under more favourable conditions.

Professor Marshall's method may thus be illustrated. Let us, with Cournot, represent ratios by logarithms, and logarithms by linear distance. But, unlike Cournot, let us take account, not only of the price, but also of the quantity of each article. Let the distance of the dot *a* from the abscissa represent the price of the first commodity, and the size of the dot the quantity consumed (per unit of time). Let the abscissa represent time. At the initial epoch, corresponding to the origin, the purchasing power of money, the denominator of the sought unit, is represented by OC, where C is the centre of gravity of the system initially. Now,

FIG. 2.



if, during the interval O T_1, only money and prices were affected, other things being constant, the required (numerator of the) *Unit* would be $T_1C'_1$, where C'_1 is the centre of gravity of the system in its new position. But other things are not constant. There occur variations, not only in the relative positions of the particles, but also in their masses (as shown by the varying size of the dots). Also new particles enter the system (*e.g.*, γ_1 at the time T_1), and old ones drop out. Thus the true centre of gravity at the time T_1 is not C'_1, but C_1. This point can be found at that time; but it is not available for our first edition of a tabular standard. The second edition at the time T_2 is similarly obtained by

comparing $T_2C'_2$, the height of the apparent centre of gravity at the later epoch, with T_1C_1, the height of the real centre at the earlier epoch. If we join the points $cc'_1c'_2$, &c., we have the locus of apparent unit hugging the corrected curve cc_1c_2.

At every step there is incurred an error, say a 'probable error,' Δu, and accordingly what may be called an improbable error about $4\Delta u$.[1] These errors being presumably independent, without bias in excess or defect, it follows, from the theory of errors, that the total error incurred in the course of n steps is $\sqrt{n}\,\Delta u$. It is a nice question how frequent the revisions of the standard should be, in order that this error may be minimised. Let Δt be that interval of time within which there cannot possibly or probably occur a change of sign in Δu, owing to a variation in those disturbances of the economic fabric which cause our standard to be inaccurate. Then it is expedient that the revisions shall take place as often as, but not oftener than, once in every such short interval. This condition points to the frequent revisals[2] contemplated by Professor Marshall.

It may be observed that Professor Marshall's solution is largely applicable to a problem kindred to ours, but which we have not supposed to be comprehended in the question set to us; namely, to measure changes in the value of money between different *places*. For instance, if the economic habits of the peoples of the Austrian empire varied by gentle gradations along a line trending from north-west to south, very much as the vital statistics of the empire are shown by Hain (in his important work on 'Das Oesterreichische Reich') to vary gradually, then it might be possible, so to speak, to carry the equation of utility from Bohemia along to the Military Frontier. It is otherwise where natural and political barriers produce discontinuity; for instance, in the case of the United Kingdom compared with the United States.[3]

SECTION III.

Determination of a Standard for Deferred Payments; not based upon the items of national consumption; calculated to afford to the consumer a constant value-in-use; no hypothesis being made as to the causes of the change in prices. (A B C d.)

We come next to the case where the items which enter into our Unit are not copied from the statistics of national expenditure, but are selected on some other principle. Although the rule in this case is different, the ground of the rule will be found to be much the same, namely, the desirability that the advantage derived from the expenditure of a unit should be as far as possible constant. To those who admit the utilitarian character of the problem (as defined by the attributes A B C) it will appear evident that a formula other than the direct solution can only recommend itself as being a workable approximation thereto.

Among methods which may seem to have a claim to that character we may distinguish the three following:—

(1) There is first what may be called *polymetallism*, the Unit based upon the price of an aggregate of specified quantities of specified metals; and not only metals but other substances which possess an attribute ascribed to the precious metals, peculiar fixity of value.

(2) Next we place the index numbers of the *Economist*, the simple average of a number of prices, especially if, as Mr. Bourne has pointed

[1] The reader, according to his habits of thought, may regard u as standing either for the sought unit or the utility which it is required to keep constant.

[2] *Contemporary Review*, March 1887.

[3] It is difficult to understand the rationale of the method by which it is proposed in the Massachusetts Labour Report for 1884 to bring together for comparison the purchasing power of wages in England and the United States.

out, care be taken to exclude the repetition of the same article in different forms.

(3) Another foundation may be afforded by a basis which Professor Nicholson (*aliud agens*, or at least not confining himself to the purpose specified in the present section) has lately laid down in the able and highly original paper which he has contributed to the March number of the 'Journal of the Statistical Society.' The new basis may be described as (the value of) the 'total mass of purchasable "things,"' ('the aggregate of purchasable commodities in the widest sense' of the term). We shall sometimes, for the sake of brevity, describe Professor Nicholson's invention as the *capital* standard.

Of these secondary methods the first and second at least have some advantage in respect of convenience over the direct solution. It is quite possible that their disadvantage in respect of inaccuracy should not be very great. The error which we incur by taking some sample commodities instead of all the items of national expenditure might be not worth correcting in view of another error with which our calculation is unavoidably affected. This is the error incident to the misfit between the consumption of the individual and that of the community. As, however, individuals resemble each other considerably in respect of consumption, there is reason to believe that this species of defect is not so important here as in the following section, where we are concerned with income derived from production (see below, p. 275).

Section IV.

Determination of a Standard for Deferred Payments; based upon the items of national consumption; calculated to afford to the consumer a value-in-use, varying with the national affluence, after the manner of a sliding scale; no hypothesis being made as to the causes of the change in prices. (A B c D.)

We now abandon the idea of a fixed standard, and attempt to construct a *sliding scale.*[1] We have hitherto supposed that the average man in paying or receiving a Unit should give or take the same quantity of wealth. But is it just, is it expedient, that, when the national wealth is increasing, the creditor should demand, the debtor pay, a *constant* quantity, or quantity proportioned to the increase of general prosperity? Probably most persons would answer in favour of the former alternative.[2] But they might be embarrassed if the principle were extended to the case of declining prosperity. Would it seriously be proposed that, if money were depreciated by the decrease of goods other than money, the debtor should pay an ever-increasing amount of currency? This seems to be

[1] The idea of a *sliding scale* may not seem at first sight to be suggested by the question set to us. It will be found, however, to be implicit in much that is written on our subject by the ablest writers—those, for instance, who, in estimating the depreciation of money, dwell upon the fact that the style of living expected in each class of life, the *Lebensansprüche*, has become heightened; those, again, who, *without entertaining an hypothesis such as that which forms the definition of our section* a (below, p. 280), still insist on including among the constituents of the Unit industrial, as distinguished from stipendiary wages, material in addition to finished products, and exports and imports, without reference to the amount of home consumption; in fine, those who would exclude wages of domestic servants, rents, and generally *distribution* as distinguished from *exchange* (on the grounds specified in note to p. 263).

[2] Cf. Poulett Scrope, *Pol. Econ.* (ed. 1833), p. 410.

one of those questions of *la haute politique* which it is not our business to decide.

If it is judged desirable that the Unit should represent a quantity of wealth varying with the national affluence, a simple method of effecting that condition is to put for the *Unit* the ratio of the national expenditure on articles of consumption at the later epoch to the corresponding expenditure at the earlier epoch. Employing the same notation as before, we have now the formula

$$\frac{\alpha p'_{\alpha}{}' + \beta' p'_{\beta} + \&c.}{\alpha p_{\alpha} + \beta p_{\beta} \ + \&c.}.$$

If it is judged desirable to compare not the absolute expenditure, but the amount relative to the number of the population, we ought to multiply the above written expression by the factor $\frac{N}{N'}$, N and N′ representing the number of the population and the earlier and later epochs respectively.

This method appears to the writer to deserve more attention than it has received. The result would probably be much the same (in the case of short intervals at least) as for the more familiar formula. But the construction would be simpler as not requiring a mean to be taken[1] between the quantities consumed at different epochs, and the philosophic basis would be free from the difficulty which besets the equation of utility.

Section V.

Determination of a Standard for Deferred Payments; based upon the amount of national income or upon prices which affect the income of any class; varying with such income or prices, after the manner of a sliding scale; no hypothesis being made as to the causes of the change in prices. (A B c d E.)

Another method of accommodating debt to the resources of the debtor is to take income as our sliding scale.[2] The received estimates of national income may be employed for this purpose. In this case the Unit might be in effect an assigned proportion of the national income per head of the population.

It should be observed that this standard, revised at most once a year, would not be adapted to the more transient fluctuations of industry. Accordingly it might be worth while to consider whether we could derive a more flexible measure of income from the prices of certain articles. Let us begin with a simple case—an importer of articles of consumption, say of the species α, who might be considered as paid by commission on the amount of his dealing. His income then varies with the price of α in the ratio $\frac{p'_{\alpha}}{p_{\alpha}}$. In the interest of this class exclusively the unit ought to be

[1] See above, p. 264.

[2] The principle of the sliding scale may be contrasted with the 'Consumption standard' in two distinguishable cases—(1) First, we may suppose national wealth, the average income, to increase (or decrease) *cæteris paribus*. In this case the proper items on which the sliding scale Unit should be based appear to consist of the expenditure on finished products (our A B c D). (2) Secondly, distribution may be supposed to vary. To adjust the Unit to this variation we have to take account of wages and other distributional transactions; also of materials as affecting the incomes of certain classes.

$\frac{p'}{p_a}$. Or, if we suppose several such dealers, we have the weighted mean $\frac{\alpha p'_\alpha + \beta p'_\beta + \&c.}{\alpha p_\alpha + \beta p_\beta + \&c.}$ (assuming that the *quantities* have not materially varied) between two revisions, and that the 'commission' of all the dealers may be regarded as the same.

Consider next residential rent and stipendiary wages. The incomes of certain classes vary directly with these payments; yet, as these incomes are not, like the preceding, equal to a small fraction, but to the entire volume, of the transactions in question, it will not be easy to combine these data with the preceding into a properly weighted mean.

Again, when we take in ordinary wages and industrial rent, we are met by the fact that, while the income of some classes varies directly with these amounts, the interest of another class, *entrepreneurs*, varies *inversely* —not indeed in exact inverse ratio, but in an opposite direction to the same quantities. Again, the materials of one manufacturer are frequently the finished products of another. Accordingly the price of such articles constitutes a very bad measure of the income of all the parties concerned.

It follows from these considerations that from an examination of prices we can obtain at most a very rough and precarious indication of the variation of resources. Such a method would be related to the more exact calculation of income very much as our method A B C d was related to A B C D.

At the same time, when we consider the purpose of our sliding scale—to mitigate the evil of industrial fluctuations—it may be doubted whether this end is not realised nearly as well by a rough-and-ready method as by the most exact calculation. For a standard based upon the vicissitudes of all cannot well be adapted to the vicissitudes of each. The fit is at best so bad that it is not made much worse by some additional imperfections of measurement.

The character and worth of such a mean variation of price as we here desiderate might be illustrated by an imaginary example of another sort of mean, one obtained by taking the average temperature for the same day over a period of years. We have known old ladies who each year discontinued and resumed fires on the same days of the year. Suppose that they had affected even greater precision, and had burned each day a quantity of fuel based upon the mean temperature for that day averaged over a period of years. It is clear that in a climate like ours those who adopted this arrangement would some days suffer from too great heat and other days from too great cold. The arrangement would be so very defective that it would not be sensibly deteriorated by some imperfections in the method of averaging the temperatures. Suppose, for instance, that in the different years the thermometrical measurements had been effected with different degrees of completeness. For the earlier years there might be (for a given day) only sample readings of the thermometer, made two or three times a day. For the later period there might be a more continuous record of temperature. Theoretically, in combining such data more weight should be given to the more complete measurements. But practically for the purpose in view such elaboration would be nugatory.

To look at the matter more closely, let us suppose with sufficient accuracy that the income of a particular class of producers depends mainly on the prices of a certain group of articles, so that it would be convenient for that particular class that the standard for deferred payment should be regulated by the movement of those particular prices. Roughly speaking, the desideratum for that class is that the unit should be proportioned to some mean of those prices; say $\frac{mp'}{mp} - \frac{\mu\pi'}{\pi}$, where p and π are prices of products and agents of production respectively. But in fact the unit must be based on the prices (and quantities) of all kinds of

articles. In view of the considerations touched in the text the ideally best combination of prices must be a complicated function, say of the form $\frac{F(p'_a, p'_b, \&c.)}{F(p_a, p_b, \&c.)}$. By an approximation admitted in mathematics, this expression may be written $\frac{ap'_a + bp'_b + \&c.}{ap_a + bp_b + \&c.}$ where the weights a, b, &c., are not (like our old friends a, β) quantities, but coefficients deduced from the quantities by the solution of a stupendous utilitarian problem. The varying relations between the quantities of things consumed or 'used up' in manufacture, and the income of different classes —such as the importers and manufacturers in the text (p. 273)—all these complex correlations must be supposed duly expressed by the function F and the derived simpler form. By an allowable abstraction we may suppose the course of industry so uniform that the coefficients a, b, &c., remain constant during the interval under consideration. We shall now show that for the purpose in hand—to mitigate the vicissitudes in each industry—it does not much matter what values (within wide limits) we assign to the weights a, b, &c. As announced in the Synopsis, almost any combination of the more important articles of trade is likely to be equally imperfect and equally serviceable.

Put for p'_a, p'_β, &c., the following: $p_a(1 + E_a)$, $p_\beta(1 + E_\beta)$, &c. And let the displacements E_a, E_β, &c., be made up of two portions, one affecting all articles equally, the other proper to each. Call the former ϵ, and let $E_a = \epsilon + e_a$, $E_\beta = \epsilon + e_\beta$, and so on. The unit which would be most desirable in the interest of a single class becomes of the form $1 + \epsilon + e_a$ (putting a single article as the representative of a small group). Meanwhile the general standard is of the form $1 + \epsilon + \frac{ap_a e_a + bp_\beta e_\beta}{ap_a + bp_\beta} + \&c.$ The first part of both expressions coincides. But it is only by accident that the remainders can be of a piece. For *by the theory of errors* the displacement (E_a) incident to a single article is likely to be of an order much greater than almost any mean of the proper displacements independently incident to n articles. As this proposition turns upon a matter of fact, the *independence* of the proper displacements of several articles, it may be well to illustrate it by some actual statistics. In the following example afforded by the immense drop of prices during the crisis of 1857, ϵ, the common displacement, is considerable.

PERCENTAGE DECREASE OF PRICES OF SEVERAL ARTICLES WITHIN A FORTNIGHT, NOVEMBER 1857.

(Based upon 'Commercial Daily List,' cited by Patterson, *Economy of Capital*, p. 191).

		Differences −	Differences +	Squares	
Tallow	17	10	—	100	
Sugar	36	—	9	81	
Cotton	14	13	—	169	
Scotch pig	16	11	—	121	
Saltpetre	31	—	4	16	
Rice	33	—	6	36	
Silk	33	—	6	36	
Linseed	17	10	—	100	
Linseed oil	20	7	—	49	
Tin	10	17	—	289	
Tea	25	2	—	4	
Pimento	40	—	13	169	
Turmeric	50	—	23	529	
Shellac	33	—	6	36	
Jute	40	—	13	169	
Hemp	16	11	—	121	
Sums	431	79	80	2,025	
Mean	27	10	10	127	= Mean square of error
				2	
				254	= Modulus squared

In this table the first column contains the percentage decrease for each article. The next two columns contain the differences between the average decrease (27), and the individual decreases. The modulus, or measure of fluctuation, is found to be about 16. Hence, by a well-known theorem, the probable error of the sum of n differences, n being large, tends to be $\sqrt{n} \times 16 \times \cdot 477$ (a theorem which does not assume that the differences are grouped according to a known curve). Suppose, for instance, $n = 9$. The probable error of the sum of n differences taken at random should be about 23. This may be illustrated by actually taking some batches of nine, say the first nine, tallow to linseed oil, the last nine, linseed to hemp, and a central nine. The sum of the first set of differences is $-51 + 25 = -26$. The sum of the second set of differences is $-47 + 55 = 8$. The sum of a third set, from Scotch pig to pimento, is $-58 + 29 = -29$; while if we put out the Scotch pig and take in turmeric we obtain $+5$. These observed results are very consonant with the theory that the probable error is 23. Hence the probable error of the *mean* of nine differences is $2\frac{5}{9}$. Meanwhile the probable error of *any single* difference may be found by observing that the 'quartiles,' in Mr. Galton's phrase, occur on the one side between -10 and -11, and on the other side between $+6$ and $+9$, giving a probable error of, say, 9. Or we may proceed more hypothetically, and, assuming that the grouping (of the differences) is conformable to the [1] normal type, find the probable error ($\cdot 477 \times$ modulus) about 8. Thus the displacement of the single article is seen to exceed the mean displacement of several articles in about the degree required by theory.

We have taken the simple (arithmetical) mean. But much the same would be true if we had taken [2] *any* weighted mean of all prices, in particular the ideally best, whose weights are ap_α, bp_β, &c. (provided at least those coefficients are not extremely unequal). The deviation of the particular standard from the general standard is apt to be so considerable that it does not much matter by what system of weights we determine the general standard. The unit best in the individual interest is, as we have seen above (p. 274), $1 + \epsilon + \epsilon_\alpha$. The unit in the general interest is of the form $1 + \epsilon + \dfrac{A\epsilon_\alpha + B\epsilon_\beta + \&c.}{A + B + \&c.}$ (putting $A = ap_\alpha$, and similarly B). The deviation of the former from the latter is of the form $\epsilon_\alpha - \dfrac{Ae_\alpha + Be_\beta + \&c.}{A + B + \&c.}$. Now, if e_α, e_β, &c., be on an average of the order e, then by the theory of errors their weighted mean, the latter part of the expression just written, will be of the order $e\dfrac{\sqrt{A^2 + B^2 + \&c.}}{(A + B + C + \&c.)}$, an expression which tends to zero as the number of the coefficients is increased. The unavoidable discrepancy between the particular and general interest is therefore not likely to be much diminished by a more exact calculation of weights when those weights are numerous.—Q.E.D.

Take, for example, the statistics above cited, where there are only sixteen items, and let us suppose the weights so disparate as the cardinal numbers 1, 2, . . . 16. If we based our unit on the simple arithmetic mean, we have $\epsilon = \cdot 27$, and for the *Unit* 1·27. Now this *Unit*, as applied to each particular interest, is apt to be out by about ·1, or 10 per cent. In the tallow interest, for instance, 1·17 would have been the best unit; if we legislated exclusively in the sugar interest the unit would be 1·36. Let us see now how these misfits would have been mended by a more elaborate adjustment of the standard. The expression $\dfrac{\sqrt{A^2 + B^2 + \ \&c.}}{A + B + \ \&c.}$ becomes when $A = 1$, $B = 2$, &c., about ·3. The correction then upon the arithmetic mean ·27 would be of the order $\cdot 3 \times \cdot 1$ (e being of the order ·1) [3] that is, ·03, or 3 per cent. This theorem may be verified by actually assigning

[1] The probability-curve.

[2] See below, pp. 290, 291.

[3] Assuming that each of the articles (tallow, sugar, &c.) is subject to the same law of fluctuation, we may conclude (from an examination of the table) that the average error for any article is 10 per cent.

the weights 1, 2, 3, &c., to the percentages above cited. The weighted mean $\frac{1 \times 17 + 2 \times 36 + 3 \times 14 + \&c. + 16 \times 16}{1 + 2 + 3 + \&c. + 16} = 28{\cdot}8$. If we reverse the order of importance, and, beginning at the bottom of the list, assign a weight 1 to hemp, 2 to jute, 3 to shellac, &c., we obtain for the weighted mean 25·6. The difference in each case between the simple and weighted mean is even less than theory predicts. Suppose the corrected unit becomes 1·25, the tallow interest will now be out by *eight* per cent. instead of *ten* per cent. from the standard best for them exclusively—no very great gain, and partly (by hypothesis of course, not wholly)[1] balanced by the loss of the sugar interest, who are now more out than before. *A fortiori* when the number of articles is greater than *sixteen.*

The general conclusion is that for the purpose in hand it does not make much matter what sort of mean we take; provided that the weights assigned to the different articles are not very unequal, and provided that there is no reason to think that the ideally best system of weights would be very unequal. The test that factors A, B, &c., are not sensibly unequal is the condition that $\sqrt{A^2 + B^2 + \&c.} \div (A + B + \&c.)$ should be small; which is true enough within very wide limits (*e.g.*, in the case of sixteen weights being respectively 1, 2, 3, &c., 16). When there are a few relatively very large interests, such as possibly in England cotton, iron, and ordinary wages, then in constructing our general sliding-scale we should pay special attention to those interests; though from the considerations mentioned above (p. 273) we are not entitled to assume that the weight to be attached to (the price-variation for) each interest is *directly proportioned* to the magnitude of the transactions.

It will be observed that this reasoning turns upon the unique interest of particular groups of persons in the prices of particular articles, on the circumstance of *division of labour.*[2] The conclusion as to the worth of our result is therefore not equally applicable to what may be called the *consumption* (A B C) as distinguished from the *production* (A B c) standard. For the rest the latter calculation resembles the former in being amenable to similar secondary modifications (see above, p. 267). For instance, upon the third of the principles referred to a variation of wages ought to affect the *Unit* more than an equal variation of profits as concerning a greater number of persons.

Section VI.

Determination of a Standard for Deferred Payments; based upon the amount of national capital; varying with such amount, after the manner of a sliding scale; no hypothesis being made as to the causes of the change in prices. (A B c d e.)

The next category is distinguished by the condition that the basis of the required sliding scale is capital rather than income. This Unit might be specially adapted to certain debts; for instance, in estimating the capital (but not the interest) of sums raised upon mortgage of fixed capital. It is interesting to enquire what sort of weight should be assigned to wages for the purpose here defined. May we measure the importance of wages as a means for paying off capital by the lump sum which the wage-earner is able to raise upon the prospect of his earnings by way of insurance?

With reference to this most important application of Professor Nicholson's method, it may be proper here to introduce a remark which is applicable also to other uses of that method. When its originator is met with the difficulty that articles do not increase uniformly, he argues

[1] If we suppose the *weights* 1, 2, . . . 16 to constitute the ideally best system, that which affords the maximum sum total of advantage to all.

[2] Compare the remarks of Von Jacob cited by Mr. Horton in his admirable chapter on the *Standard of Desiderata; Silver and Gold*, p. 39.

that 'the change in the purchasing power of the standard is found by dividing the value of the new inventory at the old prices by its value at the new.' And he is understood to regard this method as preferable to the converse method, dividing the value of the *old* inventory at the old prices by its value at the new. His reasoning turns upon the postulate, 'Let the total value of the new inventory (consisting of different quantities of the old items) reckoned at the old prices be v_1, and the total value of the old inventory, also at old prices, be w_1; then $\frac{v_1}{w_1}$ is the measure of the increase in the quantity of wealth.' In this passage read for 'old prices' *new prices*, for v_1 read w_2, and for w_1 a new symbol v_2, and you will have a postulate no less true, or no more arbitrary. According to the substituted principle, 'the measure of the increase in the quantity of wealth' is $\frac{w_2}{v_2}$; which being multiplied by $\frac{w_1}{w_2}$, by parity of reasoning with that employed by the author on the page referred to, gives for the 'measure of the new purchasing power compared with the old' $\frac{w_1}{w_2} \times \frac{w_2}{v_2} = \frac{w_1}{v_2}$; which being interpreted means dividing the *old* inventory at the old prices by the value of the same inventory at the new prices.

Observing that the 'change in the purchasing power of the standard' is the reciprocal of what we have elsewhere called the Unit, we see that the two methods just reached correspond to the formulæ (2) and (1) of our section A B C D (above, p. 264). It is important to point out that neither of these solutions is before nor after the other.[1] Otherwise there might be an objection to the use of a symmetrical mean between the two, such as has been recommended.

Section VII.

Definition of the Appreciation [or Depreciation] which it is the object of Bimetallism and similar projects to correct; no hypothesis being made as to the causes of the change in prices.

The variation in the value of money which we have been hitherto considering is that which is corrigible by the adoption of a 'Unit' for deferred payments. For different purposes different formulæ are appropriate. The purpose next in importance to the construction of a Unit (if not indeed, as some think, prior in importance and the main scope of the task set to us) is to correct the instability of trade, to restore the level of prices by augmenting the quantity of legal-tender currency, whether by Bimetallism or the increase [2] of paper-money.

Now, if we might assume all prices diminished uniformly, like the shadows of objects as the sun advances from the east, the problem would be very simple. It is an intelligible proposition that the *status quo* might be restored by an elevation of the objects all round. And the significance of the proposition need not be impaired if we suppose the objects waving and oscillating, and some of them depressed, others elevated in random fashion between the two epochs at which the shadow-lengths are observed.

[1] The question whether it is easier to get present quantities at old prices than old quantities at new prices does not come within the scope of this memorandum.

[2] *E.g.* By introducing £1 notes in England, or according to some more daring plan, such as those proposed by Professor Marshall (*Contemp. Review*, March 1887, note near end), Faucher (*Jahrbuch für Gesetzgebung*, 1868), and others.

But we are not entitled *here* to make an assumption, which is the characteristic of the following section. We must rather seek a rule adapted to the case in which one large category of objects may be considerably and uniformly elevated, another depressed; where the variations do not present any true mean or normal type. Our formula should be irrespective of such an hypothesis here equally as in the previous sections.

Upon reflection it will be found that the detriment incident to the disturbance of prices, which it is sought to correct by the augmentation of money, must be of the same general character as that which it is sought to correct by the adoption of a Unit. That creditors do not receive a constant quantity of real wealth, that debtors are disabled from meeting their engagements—these are the sort of evils which it is the object of both remedies alike to remove. Accordingly, the standards or *Units*, which have been above defined, supply the proper measure of that appreciation which it is sought to remove by augmenting the quantity of money. The currency-doctor, injecting new circulating-medium into the commercial system, may be satisfied that he has attained his object, when the standard (which[1] he has selected as the best) no longer shows symptoms of deficiency; in short, *as soon as the Unit is unity*. Thus it appears that no generically distinct method of averaging is introduced by this section. The reader may be referred to the previous sections for a description of the different methods. It will be sufficient here to note the peculiarities incident to the purpose now in hand. The operation of augmenting the currency, as contrasted with the method of making contracts in Units, presents the following four distinguishing characteristics:

(1) The infusion of money is not adapted to correct the more transient fluctuations of prices due to the oscillations of credit. As our Producer Unit—including commodities other than finished products—is specially directed to the correction of transient fluctuations, so it may be conjectured that the Unit appropriate to the present purpose (the Unit whose equality to unity is the test of the price-level being kept constant) is based chiefly on finished products, is of the nature of the consumption-standard. Not without reason does M. Walras[2] adopt this standard as the test of the currency being augmented in the proper degree.

(2) The operation of the proposed remedy requires time. The detection of the evil—the secular as distinguished from the tidal variation of price-level—also requires time. It follows that the epochs which are to be compared in respect of purchasing power are separated by a considerable interval. Hence the calculation of a Unit to express change in the purchasing power of money must be of the less exact sort, above distinguished as *integral.*[3]

(3) Again, the area which is affected by the augmentation of currency is very extensive, at least when (as in the case of Bimetallism) the added circulation consists of precious metal. Accordingly, the appreciation which is to be corrected by that remedy must relate to a very wide area, the whole system of states in monetary communication; that is, the greater part of the civilised and uncivilised world. Now, the larger and more diversified the public to which there is applied any regulation based upon the mean requirements of the average man, the less perfectly

[1] Or agreeably to Section X. a combination of different standards.

[2] *Théorie de la Monnaie*, p. 93. Cf. Professor Marshall, *loc. cit.* Horton, *Silver and Gold*, Appendix B.

[3] See p. 264.

is that type or norm likely to be adapted to the requirements of the individual. The correction of appreciation, which may be effected by the infusion of metallic money, is therefore likely to be of less benefit than that which attends the method of contracting in Units.

(4) Moreover, in the latter case the measure of the evil and of the remedy is the same. The same calculation which gives the appreciation assigns the Unit in terms of which debts are to be paid. But it is not so where the remedy is the augmentation of legal-tender money. The extent of the evil (the appreciation) having been found, the extent of the remedy is still to seek. For it is a very *naïve*[1] conception that, in order to increase prices all round in a certain ratio, it is necessary and sufficient to increase the quantity of legal-tender money in that ratio.

These imperfections of the method under consideration may be thus summed up: (1) It cannot even aim at certain objects which are within the range of the alternative method. (2) The objects which it does aim at are not sighted so clearly; its shots are apt to be very wide of the mark. (3) The advantage of hitting the mark, the prize to be won, the quarry to be brought down, is not so considerable as in the case of the alternative method. (4) Lastly, in the one case we shoot point-blank; having discovered the position of the object, we have the direction in which we ought to aim. But in the other case the trajectory has yet to be calculated, in virtue of which, being given the position of the object, we can deduce the direction of our aim.[2]

The following metaphor may assist conception. Let us represent the various commodities and their values by so many rectangular chambers filled with fluid and (more or less perfectly) percolating into each other. Fig. 1 in Sect. II. may be regarded as representing a vertical section of such a set of chambers. The height of any chamber, *e.g.*, a H or δ H^1, represents the quantity of the commodity exchanged[3] (per unit of time) in objective measure, *e.g.*, hundredweights or days' labour. The quantity of fluid per unit height represents the price of each commodity.

Now let such a change come over this system that on an average the chambers contain less fluid per unit height. Or more exactly, let the change be such that if we take here one large group of chambers, and there another (the mean of), each different group will present much the same degree of depletion. Under these circumstances the remedy for the general depletion is simple: namely, to pump fluid into (one or more of) the chambers until (by the action of percolation) the contents of the average chamber per unit height are restored to the former status.

But now suppose that the changes in the contents of the different chambers are (owing to changes in the *dimensions* of the chambers) no longer grouped about a true mean as above defined. Let the whole aggregate be divisible into two systems, for one of which the contents (per unit height) are considerably and pretty uniformly increased, for the other similarly decreased. After such a change one of the systems has its chambers much fuller (per unit height), the other much emptier, than at first. Under these circumstances it will be found a rather unmeaning problem to pour in fluid until the *status quo* of the contents is restored. *At least the meaning is no longer on the face of the data, but has to be read in 'ab extra.'* For instance, with reference to certain uses we might assign different degrees of importance to the different chambers. We might

[1] See below, p. 294.

[2] Whether these disadvantages are compensated by the greater practicability of the Bimetallistic scheme it does not come within the scope of this memorandum to consider.

[3] 'Exchanged,' rather than 'consumed,' would seem to be *here* the appropriate conception.

in virtue of such an estimate, rule that for our purposes the *status quo* of the system is preserved when we preserve constant some such quantity as the following:—The quantity of fluid contained in (a section of) one unit height of the first chamber + the quantity contained in two unit heights of a second chamber + that of three units for a third chamber, and so on. This definition being introduced, no doubt we may go on pumping in fluid until the initial plenitude is restored.

Suppose that we had control over only one element of the permeating fluid (the vapour of), a certain metallic substance which, according to undiscovered chemical laws, is apt to be combined in small proportions with large volumes of a sort of gasy material. It might be impossible to predict what amount of inflation would attend the introduction of a certain quantity of metal. The measured depletion of the fluid would not correspond to the sought repletion of the metal. We could at best only go on dropping in metal until the depletion ceased to exist.

Similarly, if one great group of commodities varies pretty uniformly in one direction, and another in a different direction (or even in the same direction, but in a markedly different degree), then the task of restoring the level of prices can no longer be regarded as a purely objective *quæsitum*, a currency problem. There is required, indeed, a monetary science much more perfect than we possess in order to adapt the means to our end; but there is required also utilitarian philosophy to define the end.

It will be remembered that these remarks are made in the supposed absence of any condition or hypothesis as to the character and cause of the price-variations. We shall now proceed to entertain such an hypothesis.

Section VIII.

Determination of an Index irrespective of the quantities of commodities; upon the hypothesis that there is a numerous group of articles whose prices vary after the manner of a perfect market, with changes affecting the supply of money. (a F.)

So far we have made no supposition as to the cause of the phenomenon which is under measurement. As far as we have been concerned there might have been a number of heterogeneous causes, or, what is even more unfavourable to calculation, a few great causes; as if one large class of prices were heightened according to the law of diminishing returns, while other prices, also forming a large class, were lowered by increased division of labour, and others by improved means of transport. We are now to entertain an hypothesis, namely, that there is an effect capable of being discovered and worth discovering, due to [1] 'causes which operate upon all goods whatever,' or at least upon a considerable group of goods; for instance, the increased quantity, or efficiency, of legal-tender money, or the improvement of money-saving expedients.[2]

The simplest hypothesis of this sort is the proposition in the text-books that prices vary inversely with the quantity of money, other things being equal. But we are not restricted to the 'Quantity Theory.' [3] It is sufficient for our purpose that there should be a circle of commodities, including money, such that the equilibrium of exchange between them should continually be readjusted by a comparatively frictionless play of

[1] Mill, *Pol. Econ.* Book III. chap. viii. s. 2.

[2] A good enumeration of causes apt to cause a general variation of prices in the case of Inconvertible currency is made by Bela Földes in the *Jahrbuecher für Natl. Oekonomie*, 1882.

[3] The discussions at pp. 294, 295 will show how far the writer is from regarding this theory as generally applicable.

market-forces. That this condition does hold approximately with respect to a large group of articles is shown in the case of Austria by Dr. Kraemer in his important work on Austrian Paper-money. From the statistics given in his Chapter III. there can be no doubt that a change in the 'valuta' of currency does enter into, and might be extricated from, the prices of a certain set of commodities. The following articles may be instanced as particularly sensitive:—*Wool, spirits, rape-seed, undressed leather*, and, in general, articles of foreign trade. These observations are supported by the copious statistics adduced by Herska, Bela Földes, and others. The only question is whether we ought not to regard all commodities, rather than only some commodities, as varying with the *agio*. No doubt it is a delicate question, and only to be decided by the proper mathematical methods of statistics, whether it is possible to extricate a mean variation in the value of money from the changes of particular prices. It seems to be so in the case of Austria. In the case of the United States, if we could accept the law laid down by Mr. Delmar as to the propagation of a change in price, we could not hope for a sufficiently large group to afford a real average. But the statistics adduced by Hock, in his history of the finance of the United States, show conclusively that in correspondence with the condition of the inconvertible currency and the state of credit there did extend pretty uniform waves of disturbance over a part, if not indeed the whole, of American industry.

The proposition which has been proved for inconvertible currency is shown to be true for metallic money—as regards, at least, a certain zone of industry—by the index numbers of the *Economist*, the statistics adduced by Soetbeer, Laspeyres, and others.

Assuming, then, that there is, or may be, over a certain region of the industrial world a mean disturbance of the sort described, it would be a significant operation to take the average of all the price-variations, *irrespective of the quantities of the corresponding commodities.* We should thus obtain a mean elevation or depression which may be described as a figure such that, if we took any ware at random, that figure [1] would be more likely than any other to be equal to the price-variation of the selected ware. A similar typical mean of human heights (irrespective of other attributes) has proved a useful implement of statistical induction in the hands of Mr. Galton, Dr. Charles Roberts, and others.

A more exact illustration is afforded by the following physical analogies. Suppose it were required to measure the force of gravitation in the neighbourhood of a mountain. Our data might consist of a set of pendulums, all disturbed from the vertical by the attraction of the mountain, and each further subject to proper disturbances. The displacement from the vertical constituting the required measurement might be found by taking a mean of the displacements suffered by all the pendulums. Now, *from what we know of the action of gravity*, there is no reason to think that the displacement of a larger mass gives in general a better measure of the common disturbing agency, the gravitation force, than a smaller mass does. Hence, in taking the mean of the displacements, there is no propriety in assigning more importance to the displacement of the more massive pendulum. If we do assign preferential importance, it should be on other grounds, namely, that the proper disturbances of some pendulums are apt to be less serious than those of others. The *combination weights* (or 'multiplier weights,' in Sir G. Airy's phrase) determined by such considerations must be carefully distinguished from the 'weight' in the ordinary sense. The pendulum weightiest in the former

[1] In short, the greatest ordinate of the curve of price-variations.

sense might be lightest in the latter sense. Another caution is to distinguish the present investigation from that whose object is the displacement of the *centre of gravity* of the system,[1] a *quæsitum* which does not presuppose any common disturbing agency.

Again the problem special to this section has been likened to the problem of discovering the proper motion of the solar system by means of the apparent movements of the stars. Let us suppose, for the sake of illustration, that the *line* in which the solar system moves has been ascertained. The only questions are in which direction of that line, positive or negative, say towards or from a certain star in Hercules, and at what rate, we are moving; how far we have moved between two given epochs. Now, if we take several groups of stars at random, say (as in fact is done) some groups in the northern hemisphere, and others in the southern, and for each of these groups we take the mean of the apparent motion of the stars along the given line; then, if the mean resultant is much the same[2] for every group, we may be reasonably certain that the phenomenon is due to a common cause, which is doubtless no other than the proper motion of the solar system. Suppose, however, that the motions of the stars did not conform to what may be called a true mean. Suppose that what Mr. Proctor calls 'star-drift' was prevalent on a much greater scale than he has found to be the case; that the Milky Way, together with other zones, moved off *en bloc* in one direction, while the Great Bear carried off another half of the heavenly host in the opposite direction. In this case we should no longer be able to detect the motion proper to the solar system. The peculiar grip which a plurality of independent events affords to the calculus of probabilities now becomes wanting.

It is to be observed that, in assigning importance to the different indications given by the apparent motions, the criterion is not the *mass* of the star, but its 'weight'[3] in the sense of affording a better measure of the *quæsitum*, the motion of the solar system.

Similarly, in the problem before us it must be either given by previous experience (as in the case of our first illustration), or discoverable from the data themselves (as in our second illustration), that there is a true mean; that one set of commodities, such as the products of extractive labour, has not risen *en bloc*, while another set, as manufactures, has fallen. Without that condition we cannot follow Jevons in reasoning by the principles of probabilities that gold has been depreciated (or appreciated) to a certain extent. With that condition we may follow Jevons in taking a mean of price-variations, *irrespective of the quantities of the commodities.*

The problem before us may be thus defined. Given a number of observations consisting each of the ratio between the new price and the old price of an article, to find the mean of these observations—the objective or quasi-objective mean—as distinguished from those combinations in the preceding sections which were prescribed by considerations of utility. The problem as thus conceived belongs to that higher branch of the calculus of probabilities which may be called the doctrine of errors. Upon the theory of errors are based two kinds of problem; of which the first is exemplified by the method of determining the true position of a star from a number of separately erroneous observations, the second, by the method of constructing the typical stature of a people, *l'homme moyen*, from the measurement of a great number of individuals. To which of these analogies—the more, or the less, 'objective' species of mean—our case most corresponds is a nice inquiry, varying with the shades of hypothesis.[4]

[1] Analogous to the calculation of Units in our earlier unhypothetical sections.

[2] If it be asked what extent of difference between the means of different groups is to be expected and may be regarded as insignificant, the answer is supplied by the mathematical Theory of Errors. See the writer's paper on *Methods of Statistics.*

[3] Depending on considerations not here relevant.

[4] Consider the illustrations given below at p. 293

Upon either view the practical rules for extricating the mean are much the same. They may be arranged under two headings, relating (1) to the form in which the given observations are to be combined; and (2) the relative importance to be assigned to the different observations.

(1) As to the first point the general rule is that, in the absence of special presumptions to the contrary, an arithmetical mean (or linear function) of the given measurements is the proper combination.[1] That is to say, if the different measurements are r_1, r_2, &c., each purporting to represent one and the same object—in our case the appreciation or depreciation of money—the proper combination of these data is—

$$\frac{w_1 r_1 + w_2 r_2 + \&c.}{w_1 + w_2 + \&c.};$$

where the factors w_1, w_2, &c., are *weights*, such that if w_1 is greater than w_2 then r_1 contributes more to the result than r_2.

This general presumption in favour of the arithmetic mean may, however, be rebutted by specific evidence in favour of some other mean, and it is here submitted that in the case of prices there does exist such specific evidence in favour of the *geometric mean.*

It appears that prices group themselves about a mean, not according to a symmetrical curve like that which corresponds to[2] the arithmetic mean, but according to an unsymmetrical curve like[3] that which corresponds to the geometric mean. Before adducing the empirical proof of this proposition it may be well to consider what *à priori* grounds we might have for preferring the geometric mean. There are[4] those who consider that the mere accumulation of agreeing experiences can seldom suffice, without some antecedent probability, to establish an inductive conclusion.

It has been shown by Mr. Galton and others that the geometric mean is adapted to a particular species[5] of observations, which may be described as *estimates.* For instance, the estimates which different persons (or the same person at different times) might make of a certain weight would be likely to err more in excess than in defect of the true objective weight, and in such wise as to render the geometric mean of such a series of estimates the proper method of reduction. This law of prizing may well extend to prices. The fluctuating estimates which from time to time a person might make of the[6] utility of an object, as measured by the quantity of some other object, *e.g.*, money, might well fluctuate according to the law which has affinities to the geometric mean. So far then as changes in price might depend upon fluctuations in demand,[7] there is something to be said in favour of our proposition.

Again, there exists a simple reason why prices are apt to deviate much more in excess than in defect:[8] namely, that a price may rise to any amount, but cannot sink below zero.[9]

[1] The ground of this presumption is partly that the arithmetic mean is one of the *simplest* methods of combination; partly that it is specially adapted to a species of observation which is very extensive *in rerum naturâ*, which may be said to be always tending to be realised, the exponential law of error, or probability-curve.

[2] The probability-curve.

[3] The curve described by Dr. Macalister in his paper on *The Law of the Geometric Mean* in the *Philosophical Transactions*, 1879.

[4] G. C. Lewis as quoted by Dr. Bain in his *Logic*.

[5] Wherever the law of Fechner applies. See papers by Mr. Galton and Dr. Macalister, *Proc. Royal Soc.* 1879.

[6] *I.e.*, the 'final utility.'

[7] Variations in what is technically called the demand-curve.

[8] As in the annexed diagram.

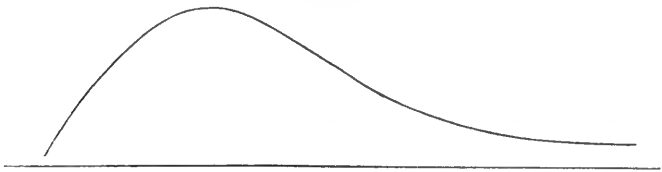
[9] That price should be, in Dr. Venn's phrase, a 'one-ended phenomenon' may raise a presumption in favour of an asymmetrical grouping, but by no means dis-

Lastly, the supposed tacit combination which everywhere exists between dealers may prevent prices falling as low as from time to time they otherwise would according to the law of supply and demand.

There is therefore at any rate no *à priori* presumption against the proposition that price-returns are apt to group themselves in an unsymmetrical curve of which the range in excess is greater than in defect. In favour of this proposition the following empirical evidence is adduced:—

In the first table are examined the prices of twelve commodities during the two periods 1782–1820, 1820–1865. The maximum and minimum entry for each series having been noted, it is found that the number of entries above the 'middle point,' half-way between the maximum and minimum, is in every instance less, and in some instances very much less, than half the total number of entries in the series. In the twenty-four trials there is only one exception to the rule, and in

FIG. 3.



very few cases even an approach to an exception. We may presume then that the curves are of the lopsided character indicated by the accompanying diagram. For the 'median' [or point having as many entries above as below it], which upon the supposition of symmetry ought to be about coincident with the 'middle point' as above defined, or at any rate as often above as below it—this median is in every instance but one (fodder, 1798–1820) below the middle point.

Fig. 3 annexed very well represents the prices of corn during the periods 1261–1400, and 1401–1540 given in Professor Rogers' 'History of Agriculture.' The abscissa in the figure represents prices, and the ordinate the number of years in which the corresponding price was enjoyed. It will be found that in both cases the maximum elevation, the greatest ordinate of the curve, occurs between five and six (shillings). Below that maximum-point, in both cases the curve does not sink more than two or three shillings (2*s.* 10¾*d.* is the lowest entry), while above that point one curve stretches out to 14, the other to 16. There can be no doubt about the fulfilment of an unsymmetrical law. Further verification of the law may thus be obtained from the earlier series of statistics. Compare the decennial averages (of corn prices) given by Professor Rogers with the annual returns on which they are based. The 'middle point,' half-way between the maximum and minimum of each decade, is in almost every case above the average. There are only three exceptions out of the fourteen decades, viz., 1271–1281, 1281–1291, 1371–1381; and one of these exceptions is not an instance to the contrary, the middle point exactly coinciding with the average.

If the prices are similarly examined by decades for linen (vol. i. p. 593), clouts, and other commodities it will be found that the rule holds, with no exceptions, or trifling ones. Thus for clouts there is not a single exception during twelve decades, 1271–1390. The only exception which Professor Rogers' statistics show is the decade 1391–1400.

penses with empirical verification. For the same presumption exists not only in the case of many anthropometrical and other statistics which prove to be symmetrical, but also in cases where there is an asymmetry in the sense contrary to the theory, an extension of the *lower* limits of the representative curve. Such are the statistics of barometrical height arranged by Dr. Venn in *Nature*, Sept. 1, 1887; the statistics of eyesight given by Dr. Chas. Roberts in the *Medical Times*, Feb. 1885; the grouping of Italian recruits by Signor Perozzo in *Annali di Statistica*, 1878.

Similar results are presented by the table of price fluctuations in the 'Massachusetts Labour Report,' 1885, p. 459. Out of seventy-eight commodities nine only have the minimum further below the average than the maximum is above it. And those exceptions are slight in respect of extent, while the exemplifications are often marked.

EXAMINATION OF VARIATION OF PRICES, 1782–1865.
(See Jevons, *Currency and Finance*, Table VIII. p. 144.)

		Minimum	Maximum	Middle point between max. and min.	No. of returns above middle	Median
Oriental products	1782–1820	65	107	86	15	84
	1820–1865	30	80	55	11	45
Tropical food	1782–1820	60	102	81	8	65
	1821–1865	34	65	49½	14	48
Metals	1782–1820	89	169	129	12	113
	1821–1865	71	123	97	13	87
Iron	1782–1820	67	139	103	16	99
	1821–1865	35	114	74½	10	55
Timber	1782–1820	54	533	293½	4	116
	1821–1865	62	137	99½	9	90
Oils	1782–1820	81	166	123½	14	105
	1821–1865	75	121	98	10	90
Dye materials	1782–1820	64	157	110½	10	98
	1821–1865	30	98	63	7	36
Fibres, cotton, wool, &c.	1782–1820	88	214	151	4	130
	1821–1860	61	121	86½	17	78
	1821–1865	61	129	95	12	88
Cotton	1782–1820	57	204	130½	2	87
	1821–1860	21	63	42	9	33
	1821–1865	21	128	74½	4	36
Corn	1782–1820	99	252	175½	9	134
	1821–1865	92	176	134	18	128
Wheat	1782–1820	81	231	156	12	131
	1821–1865	78	151	114½	18	113
Fodder	1798*–1820	118	308	213	12 (out of 23)	214
	1821–1865	156	250	203	20	199

* Return previous to 1798 wanting.

The next statistics present not time fluctuations, but place fluctuations. In the 'Illinois Statistics of Labour Report,' vol. iii. p. 340, are given the prices of thirty-eight articles in 34 different[1] towns. Examining the series of prices for each article, we find that there is fulfilled in almost every case the law that the maximum is further from the average than the minimum is. Most of the exceptions are very slight, and disappear if we take in the penultimate the observations *penemaximum* and *peneminimum*. The only real exceptions are mackerel, fresh fish, cheese, butter, and crackers, five articles out of thirty-eight. The odds against such a phenomenon occurring by accident are hundreds of thousands to one.

Lastly, let us take price returns for the same time and locality, but for different articles.

This table is extracted from Jevons' table of Proportional Variation of Prices, 'Currency and Finance,' p. 144. The 'median' is the point which has as many observations above as below it. Where, as in the majority of the rows above, the number of entries is even twelve, namely 12, the point half-way between the sixth and seventh has been taken as the median. The sixth and seventh being in almost every case close together, there is very little of arbitrariness in this procedure. The fact that the maximum is in every case farther from the median than

[1] For some few of the towns more than one price is quoted.

the minimum shows the lopsided character of the price-curves. The median has been used instead of the arithmetic mean only for convenience of calculation. Much the same conclusions would evidently have followed from the use of the arithmetic mean, as the writer has verified for the years 1801, 1821, 1831, 1851. The figures in each row overlined and underlined respectively are the pene-maximum and peneminimum. If we compare the distances between each of these and the median the series of signs is found to become 0 + + + − + + + +.

	Oriental Products	Tropical Food	Metals	Iron	Timber	Oils	Dyes	Fibres	Cotton	Corn	Wheat	Fodder	Max.	Min.	Med.	Distance from Med. to Max. compared with Distance from Min.
1783	101	87	100	97	108	94	$\underline{92}$	$\overline{112}$	102	127	110	—	127	87	102	+
1791	89	$\underline{\underline{72}}$	$\overline{100}$	92	85	82	77	96	64	112	99	—	112	64	85	+
1801	$\underline{80}$	73	139	139	167	134	108	142	114	$\overline{232}$	222	244	214	73	139	+
1811	74	60	148	106	381	136	107	149	$\underline{66}$	167	178	$\overline{308}$	381	60	148·5	+
1821	68	$\underline{63}$	101	82	116	89	74	112	53	$\overline{116}$	114	182	182	53	113	+
1831	49	$\underline{48}$	80	63	104	90	49	87	33	150	$\overline{135}$	199	199	33	88·5	+
1841	$\underline{51}$	53	90	61	113	97	40	88	37	$\overline{140}$	131	227	227	40	89	+
1851	36	41	73	36	68	90	$\underline{31}$	77	27	$\overline{98}$	78	163	163	27	77·5	+
1861	$\underline{36}$	38	88	37	69	111	32	96	39	$\overline{135}$	113	213	213	32	78·5	+

The exceptional year is 1821. If we examine the arithmetic mean for that year the exception still exists, but in a less marked degree.

Such a curve is well represented by the equation $y = \frac{h}{x\sqrt{\pi}} e^{-h^2 (\log x)^2}$, where h is a constant corresponding to the dispersion, or *écart*, of the curve (see Dr. Macalister's paper *On the Law of the Geometric Mean* ('Proc. Roy. Soc.' 1879), and compare the present writer's *Observations and Statistics* ('Cam. Phil. Trans.' p. 149). Hence, given a number of observations deviating from the mean about which they are grouped, each according to a law of the general form above stated, the most probable value of the mean deduced from these observations will be the *weighted geometric mean* given by the equation

$$\log x = \frac{h_1 \log x_1 + h_2 \log x_2 + \text{ \&c. } h_n \log x_n}{h_1 + h_2 + \text{\&c.} + h},$$

where x is the sought mean, x_1, x_2, &c., are the given observations, and h_1, h_2, &c., are the weights, of which more hereafter.

It must be remembered, however, that there may be other means adapted to represent the bias which has been observed, in particular what may be called the unsymmetrical probability-curve, elsewhere described by the present writer (*Lond. Phil. Mag.* April 1886). Nor, again, is it to be supposed that *all* statistics of prices are grouped unsymmetrically. Where the entries are average prices based on a great number of items it is agreeable both to [1] theory and the writer's observations that the normal symmetrical 'probability'-curve will set in. It will be found

[1] See in *Methods of Statistics* the statement of the proposition that the average of a *large* number of returns obeying individually *any* law of grouping tends to conform to the Probability-curve.

difficult, for instance, to trace evidence of lopsidedness in the five-year averages given by Soetbeer.[1]

The evidence adduced appears to afford a reasonable presumption that the required method of combination is some form other than the arithmetic mean, of the general character of the geometric mean. Those who have followed Jevons' investigations will be familiar with the proposal that the logarithm of the required mean or general percentage should be equated to the arithmetic mean of the logarithms of the percentages special to each article. To which it is now to be added that this arithmetic mean need not be *simple*, but may be *weighted* in the sense above indicated (p. 283); *e.g.*—

$$\log x = \frac{w_1 \log x_1 + w_2 \log x_2 + \text{\&c.}}{w_1 + w_2 + \text{\&c.}}$$

What then are these weights to be? is our *second* inquiry.

(2) The theory of errors supplies the following rules—of which the first two have been already implied in our statement of the problem—(α) In the first place no weight should be attached to a class of observations known to be affected with what is called a *constant error*, or uniform bias in one direction. It is supposed of course that only the fact, but not the amount, of the error is known; otherwise it would be possible to get rid of it. In our case this rule dictates to reject all prices which are not amenable to that play of a perfect market whose change of level we have to investigate. The writer is far from pretending that this region of permeability can at present be marked off with precision. However, a rough delimitation may be effected by researches like Dr. Kraemer's.

Assuming then that we have selected a set of percentages which may be regarded as accidental deviations from a common mean, on what principle should more importance be attached to one indication of change rather than another? The second (β) maxim which we have to apply is that the observations should be independent. This condition excludes the prices of the same commodity at different stages of production, since these prices are closely interdependent. Or, if we must take account that at each stage some fresh cause of fluctuation—source of 'error'—is introduced, at any rate each price-return is not to count for one, but only for a fraction.

Here arises the question whether a commodity extensively consumed like meat or cotton ought not to count for more, in so far as its price is a mean of a greater number of transactions, than cloves and pepper. The answer is that these transactions are not *independent*. The law that there can be only one price in a market *primâ facie* removes the presumption in favour of the more largely consumed commodity. There is no analogy between the average price of such a commodity and a mean founded upon a specially large number of independent observations in theory at least, and for the purpose of a first approximation; for it will appear in the next section that this abstract proposition is qualified by the inevitable imperfections of our statistical data.

(γ) A third principle is that less weight should be attached to observations belonging to a class which are subject to a wider deviation from the mean. Such, in our case, would be the prices of articles which, exclusive of the common price-movement of all the selected articles, are

[1] *Materialen*, pp. 99–114.

liable to peculiarly large *proper* fluctuations. Cotton and iron, for example, fluctuate in this sense much more than pepper and cloves.

The weighting of a geometric mean is a delicate matter, but not beyond the resources of science. A general rule is given by Dr. Macalister in the important paper already frequently referred to. Suppose we have a considerable series of observations belonging to a certain class, we can extract a constant which may be described as the measure of fluctuation for that series or class of observations. The constant thus given constitutes the *weight* with which we ought to affect the logarithm of an observation when we combine it, according to the arithmetic mean, with others (of a different degree of precision) in order to obtain the best possible measure. The data for determining this constant are afforded by series of prices for successive years, such as those in Mr. Giffen's *Report to the Board of Trade on Prices of Exports and Imports,* 1881–85.

If in the present state of statistics and public opinion it appears too difficult and delicate a matter to weight the data on the principle of fluctuation, the practical result of this section may be thus summed up. After the manner of Dr. Kraemer, select a number of (independently fluctuating) articles which are found to be particularly sensitive to changes in the value of money. After the manner of Jevons, find the percentage indicating the price-variation in each article, and put the geometric mean of those percentages as the required unit, or standard, or measure of depreciation. Or rather, if we must treat as equal weights certain to be unequal, it is better (for reasons which will be more fully stated in the next section) to employ a formula which is specially adapted to such jumbling of different weights: to wit, *the Median.* Examples of this species of Mean have been given above.

So far on the hypothesis that the widening circle of price-disturbance has not yet spread beyond a limited area; a case which is almost too restricted and particular to be the subject of our consideration.[1] If we suppose that the circle has completely spread, that all the compartments of the economic fabric are equally penetrated by the influence of some change in the supply of money, we have then a limiting case of the problem just discussed.

The objection to this supposition is that, for an all-pervading percolation, considerable time must, in general, be required. And then it happens—what is not necessarily true of more transient oscillations, such as those of an inconvertible currency—that the changes in prices are apt to be referable to one or two leading categories: *e.g.*, of articles which follow the law of decreasing or increasing returns, after the manner exhibited by Laspeyres in his classical paper[2] on the prices of Hamburg wares.

If we examine some of the statistics adduced by Laspeyres, according to the appropriate mathematical methods, we shall not discover a very serious hiatus between the different categories of wares. The *modulus* for the fluctuation of the price-variations about their average may be (roughly) estimated to be about 40 for any of the eleven categories discussed by Laspeyres in the masterly paper entitled 'Welche Waaren.' . . . Hence we can calculate the probability that the differences between the various categories are really significant, and not merely accidental. It will be found, if, with Laspeyres, we dispose the data in three main divisions — *Urproductionen, Colonialwaaren, Manufacte,* &c. — that the cleavages *within* those divisions are not important. The separation between the divisions is marked, yet not very serious, not more serious than is found to exist

[1] Compare the last paragraph of the *Introductory Synopsis.*
[2] *Jahrb. f. Nat. Oekon.* vol. iii. See also *Zeitschrift f. Staatswissenschaft,* 1872.

within the most perfect groups which are known to exist; for instance, the proportion of male to female births. The mean (percentage) for the first division (*Urproductionen*), containing 129 wares, is 128; for the second division, containing 85 wares, 118; for the third, containing 98 wares, 108. The modulus of comparison between the first and second mean is (*see* the writer's 'Methods of Statistics') about $40\sqrt{\frac{1}{129}+\frac{1}{85}}$ = about 5·5; while the observed difference is 10, nearly twice the corresponding modulus. Which constitutes a real, yet not enormous, difference; not greater than the differences in stature which exist between the sub-classes of a nation constituting a perfect type Similar statements are true of the comparison between the second and third means.

If in the light of these conceptions we actually plot the 312 price-variations, it will be difficult to resist the impression that we have here a *typical mean* as perfect as any presented in concrete statistics, with the exception of the circumstance not relevant to the point now examined, that the curve representing the 312 wares, however continuous, and far from being saddle-backed, is not symmetrical about its greatest ordinate; the law of price statistics above announced making itself markedly felt.

The evidence that the general average rise for the whole group of 312 articles, namely, from 100 to 118, is no mere accidental appearance, but indicative of a real agency, is mathematically estimated by odds of trillions to one.

So nearly complete a fulfilment of our hypothesis is doubtless not presented by certain other statistics, *e.g.*, some of those adduced by Dr. Forsell in his interesting brochure. But it may be safely said that no statistical argument would stand tests so severe as he applies. Consider the evidence in favour of the motion of the solar system, as marshalled in the masterly papers of Sir G. Airy and Messrs. Dunkin and Plummer in the 'Memoirs of the Astronomical Society.' It will be found that, if you omit here, and stick in there, some star of peculiarly large apparent motion, the general conclusion as to the sun's movement will be most materially altered. *E pur si muove.*

We see in the case of one example presented by one country that the hypothesis is fairly well realised by the price-variations of the majority of wholesale commodities. But it is a long step from one set of statistics to others, from wholesale commodities to the whole field of industry, and from a single country to the entire system of countries in monetary communication. Over a large area (as Leslie, Knies, and others have pointed out) there is apt to arise a marked diversity between the price-variations of different localities; a diversity which may well be inconsistent with the hypothesis of a unique and general mean type. There is no doubt that these considerations materially restrict the fulfilment of the conditions which are prefixed to this and the following section. It is possible, however, that an hypothesis, though known to be inexact, may correspond with the facts sufficiently well for the purpose in hand.

SECTION IX.

Determination of an index based upon quantities of commodities: upon the hypothesis that a common cause has produced a general variation of prices. (a f.) [1]

We have seen that, upon the supposition of a change in the supply of money, Jevons' method of combining the variations of prices without regard to the corresponding volumes of transactions is by no means so absurd as has been thought by some. The case is as if we wanted to discover the change in the length of shadows due to the advance of day.

[1] In the preparation of this section the writer has derived much assistance from repeated conversations with Professor Foxwell.

If the objects casting shadows were unsteady—waving trees, for instance —a single measurement might be insufficient. We might have to take the mean of several shadows. Now for our purpose the *breadth* of the upright object casting the shadow would be unimportant. The 'wide-spreading beech' and the mast-like pine would serve equally well as a rude chronometer.

Suppose, however, that the top of the broader tree was not level but serrated, each apex oscillating more or less independently. If by the shadow of a tree was understood the mean length of the shadows cast by all its apices, in that case the broad tree should count for more than a bare pole. How much more, would depend upon the connection between the projecting branches. The more independent the oscillations of each apex, the better the measure afforded by their mean shadow.

This image seems appropriate to our problem. Each price which enters into our formula is to be regarded as the mean of several prices, which vary with the differences of time, of place, and of quality; by the mere friction of the market, and, in the case of 'declared values,' through errors of estimation, it is reasonable to suppose that this heterogeneity is greater, the larger the volume of transactions. On this account, therefore, and irrespective of those considerations of utility which were proper to our earlier sections, greater weight should attach to the prices of those commodities whose quantities are larger. It does not follow that the weights should be proportionate to the masses. The proper coefficients could be ascertained by scientifically examining the detailed statistics of each market. But it is agreeable to the Theory of Errors [1] and to the successful practice of physicists to employ a discretionary good sense in assigning 'weights' when a precise determination is difficult or impossible. In our case a good system of weights appears to be afforded by the quantities of commodities sold (once, and exclusive of resales) per unit of time. The weight so assigned would doubtless often be too large. It might sometimes be too small in the case of commodities much resold. On the whole it would be a good and safe system. This principle of ponderation is to be combined with those which have been given in the last section.[2] If we suppose the variation of prices not confined to a particular zone, but propagated over the whole sphere of industry, then we shall obtain a set of weights almost coincident with those prescribed (upon a different ground) by the standard based on National Consumption (Section III.). For the condition that the observations should be independent,[3] leads us to exclude, or at least take little account of, the same commodity at different stages of production.[4]

[1] An improvement in weighting can only diminish, very often only slightly diminish, the error inevitably incident to the result of any measurement.

[2] See the headings α, β, γ, p. 287.

[3] See β, *loc. cit.*

[4] It would be a question whether industrial wages and industrial rent should be included, in addition to, and otherwise than representative of, the corresponding products. At any rate their weights ought not to be proportionate to their volumes; partly on account of their close connection with commodities, partly on account of the magnitude of these volumes. In the case of transactions so extensive, and perhaps we may add some other large interests such as cotton and iron, it would be best to determine the proper coefficients by specially examining the detailed statistics of each market in the light of the Theory of Errors. A summary method would be to assign to these enormous masses an averagely large weight about as large as any other weight employed in our operation. The ideally best weight is not likely to be very different from the arbitrarily assigned one, and slight differences of weight do

But though in the present operation the weights would be much the same as before, the balance, the method of combination, is different. In view of the evidence adduced in the last section that price-variations are apt to be grouped asymmetrically, the 'arithmetic' species of mean becomes precarious when our *quæsitum* is a quasi-objective type. The additional complexities which have been introduced in this section make against the geometric mean which was above recommended a certain hypothesis. There exists another species of mean more adapted to the rough character of our calculation, the Median; that is, in the simpler cases, that quantity which has as many of the given observations above it as below it, but a certain analogue of this operation, when the observations have different weights. *The required formula is the Weighted Median*, the operation designated by Laplace,[1] as the 'Method of Situation.'

The reasons in favour of the Median may be thus summed up. If, in spite of the evidence above adduced, the normal probability-curve should after all turn out to be the most appropriate representative of the group under treatment, the Median is a reduction well adapted to this case, affected as it is with a probable error only slightly larger than the arithmetic mean (Laplace, *loc. cit.* See 'Problems in Probabilities,' Phil. Mag. Oct. 1886). But if the grouping is of the geometrical (Galton-Macalister) species, the Median is still a very good reduction, coinciding as it does with the greatest ordinate of the curve denoted. Moreover, it has been shown by the writer ('On the Choice of Means,' Phil. Mag. Sept. 1887) that there is a peculiar propriety in the use of the Median when the observations are 'discordant,' when their facility-curve may be regarded as a compound made up of different families, or different members of the same family, of symmetrical curves. It is now to be added that this prerogative of the Median is retained when some or all the discordant elements are of the geometrical species. Now the phenomenon of 'discordance' is remarkably evidenced by the different degrees of dispersion which series of (*e.g.*, yearly) price-returns present in the case of different commodities. Cotton, for instance, appears to have a much larger modulus of fluctuation than Pepper. Add that this method of reducing observations is the least laborious of all, and there will remain no doubt that in the present state of our knowledge, and for the purpose in hand, the Median is the proper formula.

The method of the Weighted or Corrected Median may best be described by an example. The first column of figures given below are price-variations, expressed as percentages, for nineteen commodities, obtained by comparison of the year 1870 with the period 1865–9. The figures are taken from table 26 of the Appendix to the Memorandum contributed by Mr. Palgrave to the Third Report on the *Depression of Trade*. The percentages given by him are here rearranged in the order of magnitude. Opposite each percentage in the third column is given the proportional quantity of commodity, or 'relative importance,' taken from Mr. Palgrave's table 27 (year 1870). The fourth column contains the (approximate) square roots of these quantities.[2] Now for the *simple* Median the

not appreciably affect the result; as may be seen by comparing the results corresponding to two different systems of weights (see note 2 on this page).

[1] *Théorie Analytique*, Supplement 2. See the present writer's paper on *Observations relating to Several Quantities* in 'Hermathena' (Dublin), 1887.

[2] The quantities of commodities taken as weights correspond to the *squares* of Laplace, p_1, p_2, p_3, &c. (*loc. cit.*) If we determine the Median by way of the third, instead of the fourth, column, we in effect assign for our system of weights the squares of the masses. This operation, indicated by the bars in the third column, gives 91 as the Median. It is interesting to observe how small is the difference produced by the change of system—small in relation to the error incident to any

rule is to find that one of the entries in column 2 which has as many observations above as below it: that is the *ninth* in the order of magnitude; which proves to be 94. For the *weighted* or corrected Median we still seek the entry in column 2, which has as many observations above it as below it; but we proceed as if the observation 71 had been made, not once, but 19·5 times; the observation 72 made 12·8 times, and so on. There being in all nearly 177 such constructive observations, the Median is the 89th, that is 94. Or in other words we have to find in the fourth column that figure which is such that the sum of all above [or below] it *with* the figure itself should be greater than half the sum of the entire column, but *without* that figure should be less than half the entire sum. The figure thus defined proves to be 6·2. For the sum of the entries above that figure is 82·3, and the half sum of the column is 88·25. Now 82·3 is less than 88·25, while 82·3+6·2 is greater than 88·25. The entry in the second column which corresponds to the figure thus determined, viz., 94 (corresponding to 6·2), is the required *Weighted Median.*[1] The weighted Arithmetic Mean as calculated by Mr. Palgrave is 90.[1] By a similar operation performed on the export statistics for the year 1880, given by Mr. Giffen in his report of the year 1881, it is found that the Weighted Median (for the decline of price compared with 1861) is −7·8. Mr. Giffen's result, the corresponding Weighted Arithmetic Mean, is −5·83.[1]

Commodities	Price-variations	Quantities	Square roots of quantities
Cotton	71	381	19·5
Wool	72	164	12·8
Tobacco	75	17	4·1
Wheat	80	418	20·5
Copper	82	30	5·5
Coffee	89	8	2·8
Tea	90	66	8·1
Flax	91	82	9
Oils	94	38	6·2
Lead	95	21	4·6
Leather	97	55	7·4
Iron	97	128	11·7
Silk	98	49	7
Tallow	101	44	6·7
Meat	102	382	19·5
Timber	104	150	12 2
Indigo	107	9	3
Sugar	120	143	12
Tin	120	15	3·9
		2,200	176·5

The operation is much simplified by noticing that it is sufficient to arrange the percentages in the order of magnitude *in the neighbourhood*

Mean; which, as rudely estimated from the dispersion of the entries in the first column, is as likely as not to be as much as 2 or 3, and may not improbably be 4 or even 6. The difference between the systems is apt to be less, when the number of independent entries is greater. In the example cited from Mr. Giffen's statistics (where the number of entries is 58) the two systems of weights give *identical* results.

[1] As to the import of these discrepancies see the preceding note.

of the median. For instance, if we are certain beforehand that the mean is below 100, we may dispose the entries above that figure in any order, just as they occur in the table from which they are taken.

We have shown how to construct a type of price-variations analogous to the *typical mean* of statures or other attributes defined as that height, or it may be weight, which appertains to a greater number of a certain population than any other height or weight does.[1] But here it may be asked, Why rest satisfied with a type if there exists a more substantial *quæsitum*? Why seek the mean variation of shadows instead of the objective movement of the bodies, that declination of the sun or revolution of the earth of which the varying shadows are the expression? Why not penetrate beneath the superficies of shifting prices to the real relations between the quantity of money and commodities? [2]

The matter is simple as long as we keep to the abstract theory of the text-books. Imagine a purely metallic currency, the amount of which is, say, Q, and let the rapidity of circulation or duty of money be called C; then we may simply express the quantity of metallic money in terms of prices and volumes of transaction in our notation

$$Q = \frac{1}{C}\left[\alpha p_\alpha + \beta p_\beta + \&c.\right].^3$$

Now let prices vary with the quantity of money, other things being constant, and we have for the variation in the quantity of money the simple expression

$$\frac{\alpha p_\alpha + \beta p_\beta + \&c.}{\alpha' p'_\alpha + \beta' p'_\beta + \&c.} = \frac{Q}{Q'},$$

where $\frac{\alpha}{\alpha'} = \frac{\beta}{\beta'} = 1$, &c., nearly, or upon an average.

Let us now introduce the several concrete circumstances, *first* that a proportion, say the ratio K, of transactions is effected by credit; *secondly*, that the volume of transactions varies between the epochs under comparison, say is multiplied upon an average by the factor P; *thirdly*, that the proportion of credit transactions, and *fourthly*, the duty of money, the coefficients C and K, do not remain constant.

When we introduce the first attribute alone, no difficulty is felt. The factor K disappears and leaves our formula in its initial simplicity. Again, when we introduce by itself the attribute of increased volumes, no great complication arises. We have only to multiply the simple formula by P in order to obtain the diminution of metallic money relative to the volume of transactions, *per unit volume* as one may say.

This proposition may appear at first sight still to hold good when we combine the two attributes hitherto considered separately. But this presumption is negatived by the fact that legal-tender money is largely

[1] The Mean as defined in Dr. Charles Roberts' writings, not quite identical with Quetelet's *homme moyen* in case of asymmetrical curves like that on p. 284.

[2] What we have so far found is a mere ratio, comparable in point of objectivity to the ratio between male and female births (about 1,040: 1,000 in England). But might the analogue be the proportion of black and white balls in large groups of balls which have been drawn at random from a huge urn? Beneath the typical mean presented by those groups there is a more objective fact; the relative numbers of black and white balls, the masses of ebon and ivory.

[3] By α, α', &c., for the purpose in hand we should understand not so much the amount of things sold as the amount of sales (per unit of time).

used in modern industry, by way of *reserve*, to meet the residues of claims not mutually compensated. It is shown by the present writer in his paper on *The Mathematical Theory of Banking*[1] that, theoretically and abstractedly, reserves tend to vary as the *square root* of the volume of transactions which they support. The reserve of material money and the mass of credit transactions are to each other, as Mr. Giffen says, as the little weight and the big weight at the ends of the unequal arms of a lever. But it is a lever of a very peculiar mechanism, such that, when you increase the big weight, you lengthen the long arm. It will be understood, of course, that this doctrine is quite abstract and ideal; related to banking business very much as the 'quantity theory' to hard-cash transactions—'the most elementary proposition,' as Mill says of the latter theory, and without which 'we should have no key to any of the others.'

The proper factor, therefore, is no longer P. The mildest expression for the correction now required is of the form $(1-K)P + KJ\sqrt{P}$, where J is a new and probably unascertainable constant. That is theoretically[2] the sort of ratio by which, when the volume of trade increases, the mass of metallic money should be increased, in order to drive the trade at an unaltered level of price.

Now introduce the attribute that the ratio of credit to hard cash varies with time, and the varying ratio of the mass of metal to the volume of transactions, as we have good reason to believe.[3] Superadd the circumstance, which we have no reason to deny, that the rapidity of circulation also varies, and it is evident that the investigation which we have attempted is blocked by insurmountable statistical difficulties.

We might get a little further no doubt if we assume an additional datum, R, the ratio of gold in reserve to gold in actual circulation; then, with the help of P and K and R, as it were rail off from the industrial world a zone of hard-cash transactions to which the abstract formula of the text-books is applicable. This method has been pursued by Professor Neumann Spallart and Dr. F. Kral in the elaborate monograph *Geldwert und Preisbewegung.*[4] It certainly seems possible by this method[5] to explain the fact, if not to measure the magnitude, of a rise or fall of general prices; to predict the direction of the change, whether positive or

[1] *Report of the British Association,* 1886.

[2] K and C being still supposed constant.

[3] Cf. Giffen, *Stock Exchange Securities,* 'To give it [the abstract theory] validity, it must be assumed that a scarcity of money produces no expedients for economising money, and that an abundance of money does not lead to want of economy, which can hardly ever be the actual condition of life.'

[4] *Staatswissenschaftl. Studien,* n. v. Dr. Ludwig, Elster, Jena, 1887.

[5] The modest hope of explaining accomplished facts is not encouraged by Dr. Kral's success. For *à priori* he finds that the store of gold in Germany during the last few years has been fully adequate to the work which it has had to do—account being taken of rapidity of circulation and the amount of credit transactions. There have been no symptoms of a 'Geldmangel,' that is to say (see p. 262, top) no reason to expect a rise of the purchasing power of money, a general fall in prices. Yet *à posteriori* it seems to be admitted that there has been such a fall of prices. That this fall has originated 'auf Seiten der Waren,' that it is due to the development of industry rather than the introduction of the 'Goldwährung' into Germany, may be a fact. But that fact does not seem to annul the right we have to expect a correspondence between the two lines of investigation; namely (1) the comparison between the supply of money and the amount required in order that the level of prices may be steady; and (2) the observed level of prices.

negative, required in the amount of currency, in order that the level of prices may be restored.

It would be foreign to the spirit of this memorandum to dwell upon ordinary statistical difficulties. But there is one scruple inherent in the nature of the metretic art which even with the progress of statistical technique does not seem likely to be removed. The method under consideration requires the determination of a certain residue, viz., total volume of transactions *minus* the portion effected by credit, $V-C$ in Dr. Kral's notation. Now each of these quantities, and *à fortiori* their difference, is subject to an error of measurement. And statistics must be much more perfect than there is any prospect of their being in the immediate future in order that the error incident to each of these measurables should not exceed a hundredth part of the same. But the hundredth part of the total transactions is a quantity of about the same order as that which it is sought to determine, namely, the amount of transactions in hard cash. The latter quantity, therefore, will be apt to be lost in a fringe of error. And, though the methods of determining V and C are likely to improve, yet the ratio of $V-C$ to V or C is certain to diminish, so that the precariousness of the calculation may well remain constant.

Upon the whole it seems that in the present state of science we must abandon the sort of realism which seeks an additional entity behind the phenomena of varying prices. We must resign the fond idea of finding in the mean variation of price any quantity more objective than itself, any measure of its cause verifiable by an independent statistical investigation. We must be content with measuring the shadows; the objects behind them are beyond our reach. The cause of the observed phenomenon may be vaguely indicated as the changed relation between shining orb and opaque bodies; but there is wanting the mathematical science which should express the varying length of shadow as a definite function of the position of the sun.

The only question is whether we should not adopt a less, not a more, objective *quæsitum* than the type above described; whether, even where we can use the semi-objective type peculiar to this and the preceding section, it would not be better to use the more subjective formulæ investigated in the earlier sections. The present writer, following Laplace, has maintained [1] that, even in the case of physical observations relating to a real thing, the proper method of combination is not so much that which is 'most probably' [2] correct, most frequently in the long run the true measure, but that which may 'most advantageously' be employed. *A fortiori*, when our *quæsitum* is at best a type, the proper mean may well be not the ratio which is presented by the greatest number of (independently oscillating) prices,[3] but that ratio which in reference to human uses it is best to adopt in any general regulation.[4] However a peculiar import-

[1] *Metretike*, part ii.

[2] Laplace.

[3] In the case of our metaphorical shadows suppose that the scope and end of the measurement was to ascertain whether and by how much shade for the use of man and his cattle was increasing or decreasing with the change of hour. The determination of a mean variation in the length of shadows would be useful only as a step towards that end. It would be better to aim directly at the end, and combine arithmetically the length of the shadows multiplied by the corresponding breadth; this system of weights being now determined, not on the principle proper to this section (see above, p. 290), but on the ground that the broader trees are the more umbrageous.

[4] Read Professor Foxwell's very able lecture on *Irregularity of Employment and Fluctuations of Prices*, and consider *what* it is, what sort of mean or function of

ance may be attached to the character of objectivity, when the result of the investigation is to form the basis of action for Governments or International Conventions. It is fortunate that the difference between the two species of Means is likely to be inconsiderable numerically.

Section X.

Mixed Modes; compounding the ends or means of several distinct methods.

$$\Big(\mathrm{A\,B}\,[\mathrm{C}+\mathrm{c}]\Big);\ \Big(\mathrm{A\,B\,c}\,[\mathrm{D}+\mathrm{d}]\Big);\ \Big(\mathrm{A}+\mathrm{a}\Big);$$

$$\Big([\mathrm{A}+\mathrm{a}]\,[\mathrm{B}+\mathrm{b}]\,[\mathrm{C}+\mathrm{c}]\,[\mathrm{D}+\mathrm{d}]\,[\mathrm{E}+\mathrm{e}]\,[\mathrm{F}+\mathrm{f}]\Big).$$

We have now examined all the branches represented on our tree. But we have by no means exhausted all the possible ramifications; for, according to the logic of compartments or combinations, six bifurcations—the number of our principles of division—lead to sixty-four distinct branches. It is further to be observed that two or more branches may unite to form a compound arm. Two or more separate objects may be simultaneously pursued. For instance, a Unit might be required which could combine the attributes C and c, which should be adapted as far as possible to the convenience of the economic individual, both in his capacity of spender and earner. There might be sought the best possible compromise between the conditions that the creditor should receive a constant quantity of value-in-use and that the debtor should pay an amount of money varying with his resources. This middle course might be designated by the symbol A B (C+c). Or, if we start with the conception of a sliding scale, and base it partly on finished products, partly on other items (as materials or wages), we have the Mixed Mode A B c (D+d).

Again, there seem to be combined in popular thought two elements which we have sought to distinguish in analysis, namely, the conception of an objective mean variation of general prices, and the change in the power of money to purchase advantages. It is as if having to measure the intensity of a drought we were to observe the decline of rainfall in every district over the whole country, and to take the mean of those observations; while at the same time keeping an eye to the fact that peculiar interest and importance attach to the decline of rainfall in certain regions, namely, those which constitute the catchment basins of the rivers which supply the population with water. The most comprehensive combination is that represented by our last symbol, purporting to be a compromise between all the modes and purposes [1]—*the* method, if practical exigencies impose the condition that we must employ one method, not many methods.

Doubtless, practical wisdom lies in a mean, and compromise is of the essence of common sense. Some of the most useful plans and institutions are those recommended by a jumble of heterogeneous and incommensur-

prices, which he requires to be kept constant: whether it is what we have called the *Producer's Unit* (A B c), or some more objective mean of all price-variations weighted by the corresponding volumes of transactions.

[1] Including many purposes which have not been thought worthy of a separate place here—for instance, to find the increase of National Wealth, given the total value at two epochs.

able considerations, like the celebrated resolution [1] declaring the throne vacant after the flight of James II., of which Macaulay says that 'its object was attained by the use of language which in a philosophical treatise would justly be regarded as inexact and confused. . . . The one beauty of the resolution is its inconsistency. There was a phrase for every subdivision of the majority.'

There seems no more to be said, if what is required of us is a political measure rather than a scientific measurement. But, if otherwise, there is desiderated a *principle* by which to effect a synthesis between the purposes separated by our analysis. Perhaps it would be wisest frankly to acknowledge the arbitrary character of the proposed operation—

> quæ res
> Nec modum habet neque consilium, ratione modoque
> Tractari non vult.

If a more definite answer is insisted upon, one might propose for imitation the Scotch practice of 'striking the Fiars' [2] by means of a jury. A committee of experts agreed as to the general scope of the inquiry might be brought together, or put in communication.[3] Each member should independently form a numerical estimate based upon the data submitted to all. The *mean* of all these estimates constitutes the best possible value. It is thus that juries having to assess damages frequently proceed. The principle is illustrated by the following experiment. Ten gentlemen agreed each to guess the age of all the others and to state his own. The statistics so obtained evidence that a better estimate is afforded by the mean of several judgments than by the individual opinion. (For details see *Mind*, Jan. 1888.)

No doubt it is a delicate problem in the higher *Metretics*, what degree of divergence in principle between authorities would be fatal to the collation of their judgments. Jurymen who differed materially as to the law or facts of a case could not with reason or advantage take a mean between their individual assessments. Similarly our monetary jury must be supposed to be agreed as to the general scope of the inquiry. Minor differences of opinion might be waived. The discrepancy between the various received formulæ for the Consumption Standard [4] would not be fatal, or rather would be favourable,[5] to the combination of all the estimates into a mean result likely to be less fallible than any one of the measurements thus averaged. The methods of Messrs. Sauerbeck, Mulhall, Sidgwick, Marshall, Palgrave, Giffen, Lehr, and perhaps it may be added, Drobisch, and the one which is specially recommended in this memorandum,[6] may be advantageously mixed. But, on the other hand, those who hold with the present writer that, in the construction of a standard for general purposes, a unique importance should attach to the items of National Expenditure—the average budget—the numerous

[1] 'It was moved that King James the Second, having endeavoured to subvert the constitution of the kingdom by breaking the original contract between king and people, and, by the advice of Jesuits and other wicked persons, having violated the fundamental laws, and having withdrawn himself out of the kingdom, had abdicated the government, and that the throne had thereby become vacant.'—*Macaulay*, chap. x.

[2] See W. K. Hunter's description of this practice.

[3] M. Dabos, in his *Etalon*, is perhaps the only writer who has frankly asserted that the value of gold is a metaphysical matter to be decided by cultivated intelligence.

[4] Above, p. 264. [5] P. 266. [6] Section IV.

adherents of this *Consumption-Standard*, might not consent to merge an estimate so formed with the results of those who adopt a fundamentally different principle; for instance, Dr. Geyer's method, or another mentioned by him, which may thus be described. Take the price of each ware, just as it has been quoted. Add together these figures. The ratio between this aggregate at one epoch and the aggregate at another is put for the measure of the variation in the purchasing power of money.

The doctrine of the Mean, or principle of collated authority, admits of a certain analogical extension beyond mere arithmetical results to the determination of a function or form of combination. Accordingly that solution of our last problem, which is offered in the Report herewith printed, derives a certain confirmation, and the only sort of proof of which it is capable, from the general assent which it has received from the Committee of experts who have been appointed to consider this subject. A short analysis of that Report may fittingly conclude this Memorandum.

The first part of the Report points out the necessity of distinguishing in theory several ends and methods [such as those which have been analysed in the preceding sections], the expediency of in practice giving precedence to some one mode [such as it is the main object of this section to discover].

Part II., A, of the Report sets forth this mode, 'the principal standard.' It is a compromise between the principles of the Consumption-Standard, A B C D, and the more objective Mean, a f; an unequal compromise, inclined in favour of the first principle.[1] Agreeably to the first principle, yet without prejudice to the second,[2] the 'weights' of the price-variations are the quantities of commodities. The form of combination, the 'arithmetical' mean (or linear function), is prescribed by the first principle. In deference to the second principle, if not entirely on account of statistical exigencies, the prices used are wholesale prices, and the items of domestic service and residential rent have been excluded.

Part II., B, of the Report propounds six 'subsidiary' index-numbers. Of these, three, *Wages*, *Workmen's Budgets*, and *Exports and Imports*, may be regarded as corresponding to those 'partial interests,' which were noticed at the end of the *Introductory Analysis* as of especial importance. Of the remaining three, the index-number based on *Wholesale Goods in General* may be perhaps put for the Producer's Standard, here designated A B c d E.[3] There remain the Consumption-Standard, A B C D,[3] and the Capital-Standard, A B c d e;[3] the former pure and simple, the latter shorn of the item of labour, to which it may have some claim.[4]

Considering the importance of the last-named species, it may be well to justify our treatment of it, in not only curtailing its items, but also not adopting it (in preference to the Consumption-Standard) as the framework of the 'principal' index. It will be recollected that the

[1] In giving these reasons the writer speaks only for himself.

[2] See Section IX. p. 290.

[3] For convenience of reference the symbol B has been retained here; but the meaning would be more exactly expressed by omitting it, or substituting (B + b). We are not here concerned to distinguish whether the index-number is to be used as a *Standard for deferred payments*, or with some other view.

[4] See p. 276.

peculiarity of this standard, which Professor Nicholson has recently proposed, is its taking as the measure of the purchasing power of money not the value of the quantity of things consumed, but the quantity of things in existence, the amount of things saleable rather than of things sold. This is certain to be a good method, in so far as it is not likely o differ much from the Consumption-Standard.[1] It might be dangerous in so far as it attaches weight to a comparatively unimportant dimension, the projection into the future of present value.

Let us figure different categories of wealth, divided according to the attributes of fixity and proximity to their final cause, by the image of trees bearing fruit, some ripe for consumption, some coming on. It is an intelligible principle that the importance of each botanical species is measured by the money value of the fruit of that species which is consumed in a day or year. But, according to the new principle, the marks of importance are the longevity of the tree and the time which the fruit takes ripening. But what if a fruit much in vogue be of the nature of an annual? The gardener, taking stock of the orchard, may value the existing plants of this species at less than the perennial trunks, which will yield to a late posterity a comparatively little desired product. But the general public may be much more concerned by a change in the price of the former article.

According to the new principle, ducks' eggs shall count for more than hens' eggs, other things being equal, if the former fowl lives longer. Reasonably, it may be urged, for the longer-lived fowl is more valuable. Yes; but if the same number of ducks' eggs and of hens' eggs are, *exempli gratiâ*, eaten each year, then *fewer* ducks will be used up each year in order to supply the egg market. Whether, then, we compare the two interests by way of the eggs or of the fowls, the Consumption-Standard gives a consistent and plausible result. Again, suppose a watch costs ten times as much as an umbrella, that everyone who has an umbrella has a watch, and everyone who has a watch has an umbrella, and let a watch last ten times as long as an umbrella. At any given moment there are in existence as many watches as umbrellas, but in every year there are ten times more umbrellas than watches used up. According to the Capital-Standard watches shall count for ten times as much as umbrellas; for just as much according to the Consumption-Standard. Which is the more reasonable?

It is contended that the new principle has the advantage of being definite and determinate.[2] This is a modest claim, and one which cannot be refused to the simple unweighted index-number, or indeed to any assigned random principle of selection; for instance, that each article should have a weight varying with the position in the alphabet of the initial letter of the English word which designates the commodity. But

[1] In so far as estimates are based upon income, and income is coincident with expenditures, there might not be much difference between the three principles which we have designated by the letters D, E, e. In practice the difference might become evanescent in virtue of the theories relative to the effect of different *weights* upon the resulting mean, which we have given in our fifth section.

[2] It has been objected that the present writer should not throw stones against a standard possessed of 'objective' solidity, while he himself occupies the position of a glasshouse construction based upon illusory utilities. It should be observed, however, that the Consumption-Standard, in that it is based upon definite and, as it is found, steady returns of National Expenditure, has just as much claims to objectivity as a standard based upon the items of the National Inventory of all vendible articles.

the (unmodified) Capital-Standard has not even this degree of definiteness. For, though with respect to embodied utilities it affords a determinate and serviceable criterion, namely, the value (depending upon the durability) of the material substratum; with respect to incorporeal vendibles, to services —as Professor Sidgwick has acutely pointed out—there exists no definite measure upon the principle under consideration.[1] Professor Nicholson speaks of 'the labour of a British working man for a quarter of an hour.' But why take the *minimum divisible* of a day's work (if a quarter of an hour is such)? The largest multiple, rather than the least measure, would seem to be recommended by analogy. Shall we say a year, or seven years —the period of the oldest labour-contract on record—or the period for which soldiers sell their services? In seeking the appropriate *quantum* we seem to float about on an infinite sea of arbitrariness, once we leave the moorings of the Consumption-Standard.

In short the Capital-Standard is *a* method, and a good method; but it has no claim to be regarded as *the* method: to be preferred before the index based upon Consumption, or to constitute 'the principal standard.'

In concluding this paper, the writer desires to acknowledge gratefully that he is indebted for many important suggestions and corrections to his colleagues, the fellow-members of this Committee, especially Professor Foxwell.

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[1] It may be held, perhaps, that it is allowable to omit productive labour as being paid out of the product (cf. the *fourteenth* page, third paragraph, of Prof. Nicholson's paper). Upon the principle of the *Consumption-Standard* it is of course proper only to count finished products (or wages and materials, as representative of, but not along with, finished products). But, in the case of a standard which is based upon the 'aggregate of purchasable commodities in the widest sense' (*op. cit.* p. 257), it is not at all clear why any commodity should be omitted because its 'result appears' (*op. cit.* p. 266) in the form of a finished product. By parity we should omit all unfinished products.

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Second Report of the Committee, consisting of Professor T. McK. Hughes, Dr. H. Hicks, Dr. H. Woodward, *and* Messrs. E. B. Luxmoore, P. P. Pennant, Edwin Morgan, *and* G. H. Morton, *appointed for the purpose of exploring the Cae Gwyn Cave, North Wales. (Drawn up by* Dr. H. Hicks, *Secretary.)*

The main object that the Committee had in view this year was to extend the excavation which had been made in front of the new entrance to the cavern, discovered last year, so that a clear section of the deposits which covered that entrance might be exposed.

Work was commenced on June 6 and continued to the 18th, when it was decided that a sufficient excavation had been made, and work was for the time suspended. It was deemed advisable to postpone the shoring up of the sides and any filling in that may be required until August, so that an opportunity may be given to anyone interested in the exploration to examine the section exposed. The excavation was visited daily by some members of the Committee, and all, excepting Dr. H. Woodward, were able to be present on several occasions. The section has also been examined by Professor Boyd Dawkins, F.R.S., Messrs. C. E. De Rance,

F.G.S., R. H. Tiddeman, F.G.S., Clement Reid, F.G.S., A. O. Walker, F.L.S., H. C. Beasley, and others.

It was found necessary to remove much of the timber placed last year to support the face in front of the entrance, so that the section might be clearly exposed, and the cutting was widened here sufficiently to show a vertical face of undisturbed deposits. The timber supporting the north-east face of the cutting was allowed to remain, as that portion had been well exposed last year, and it was thought that the excavation in front and to the south-west would yield all necessary evidence without incurring that additional trouble and expense. The cutting was carried in a south-south-west direction from the mouth of the cavern, and beyond the dip in the field supposed to indicate the line of an old fence; the length from the timber on the north-east face to the commencement of the dip in the field being about 30 feet and the width varying from 5 to 10 feet; the narrowest part being at the furthest point from the cavern. In the face exposed in front of the entrance, and for a distance in the cutting from there of about 25 feet, the soil varied in depth from 18 inches to 2 feet, but at the slope supposed to indicate the line of the old fence it thickened considerably. Underlying this throughout the whole length of the cutting and in the field beyond this point, a boulder clay of a reddish-brown colour was exposed. This boulder clay contained thin seams of sand, which were traceable generally at the same horizon along the whole section.

At a depth of about 7 feet from the surface, in a continuous band of reddish sandy clay, numerous fragments of marine shells and some perfect ones were met with, and these have been recognised by Mrs. McKenny Hughes to belong to the following species, viz. *Ostrea sp.*, *Mytilus sp.*, *Nucula nucleus*, *Cardium echinatum*, *C. edule*, *Cyprina islandica*, *Astarte borealis*, *Artemis exoleta*, *Venus gallina?* *Tellina balthica*, *Psammobia ferröensis*, *Donax?* *Mya truncata*, *Littornia sp.*, *Turritella terebra*, *Buccinum undatum*. Below the boulder clay, at a depth of about 9 feet from the surface, there was exposed some sandy gravel and fine banded sand with a total thickness of over 6 feet, and under the latter a well-defined band of finely laminated reddish clay.

Below the laminated clay the brecciated bone earth was found to extend as far as the cutting was made in front of the entrance, and also for a distance of 7 feet in a southerly direction from the entrance. This year only a few fragments of bone and bits of stalagmite were obtained from this earth, though it will be remembered that last year it yielded many teeth as well as the flint flake which was discovered near the entrance. The limestone floor under the bone earth was found to rise gradually outwards from the mouth of the cavern for some distance, forming a shallow basin-shaped space in front of the entrance. In the bone earth in this space there were several large angular blocks of limestone.

It was not thought necessary to dig down to the floor along the whole length of the cutting, but it was traced for 7 feet in that direction by the side of the cliff against which the deposits abutted. Beyond that point the cutting was made deep enough to reach the sandy gravel under the boulder clay, and at different parts test-holes were sunk still deeper into the gravel and sand. One hole was also sunk in the field in front of the cutting at a distance of over 35 feet from the entrance to the cavern. The deposits here were found to be similar to those in the cutting and in front of the cavern, but the depth of soil over the boulder clay was only

from one foot to 18 inches. A very large number of smoothed and ice-scratched boulders were found, many of considerable size; the majority being fragments of Wenlock shale from the neighbourhood and Lower Silurian rocks from the Snowdonian area. Amongst them also were fragments of granite, gneiss, quartzites, flint, diorites, basalts, carboniferous rocks, &c.

Report of the Committee, consisting of Professor SIDGWICK, Professor FOXWELL, Mr. A. H. D. ACLAND, *the* Rev. W. CUNNINGHAM, *and* Professor MUNRO (*Secretary*), *on the Regulation of Wages by means of Lists in the Cotton Industry.*

SPINNING.

AT the present time there are nine lists regulating wages in the spinning branch of the cotton industry. The number of persons whose wages are affected by the lists is about 55,500—viz., 18,500 minders and 37,000 assistants. The card-room hands, numbering about 60,000, possess no list. They are, it appears, comparatively unorganised.

LISTS IN OPERATION.

The Committee have been able to secure the following lists:—

List	Where in operation
1. Blackburn, 1867 . .	Blackburn, Accrington, Church, Haslingden, and Pendlebury.
2. Burnley, 1867 . .	Burnley.
3. Preston, 1866 . .	Preston, Bamber Bridge, Cuerden, Farrington, Gregson Lane, Lancaster.
4. Bolton . . .	Bolton, Atherton, Chorley, Farnworth, Hindley, Leigh Spinners, Manchester (partly), Reddish, and Tyldesley.
5. Bury, 1867 . . .	Bury, Rochdale (partly).
6. Hyde, 1872 . .	Hyde.
7. Stockport, 1867 . .	Stockport.
8. Ashton-under-Lyne .	Ashton, Bollington Coarse Spinners, Droylsden, Macclesfield, Mossley, and Stalybridge.
9. Oldham	Oldham, Coldhurst, Chadderton, Higginshaw, Hollinwood, Huddersfield, Littleborough, Lees, Manchester (partly), Middleton, Middleton Junction, Over Darwen, Rochdale (partly), Royton, Shaw and Crompton, Warrington, and Waterhead.
10. The old Ashton List.	
11. The new Bolton List of 1887.	

Many spinners in districts outside those mentioned adopt one of the above lists for their factories, and there is no doubt but that these lists give a correct statement of wages for the whole spinning trade.

TECHNICAL TERMS USED IN THE LISTS.

Without some knowledge of the spinning trade it is impossible to understand fully the technical terms used in the lists. The following brief statement may assist in grasping the nature of the lists.

The spinning machine is technically called a mule. It varies in size according to the number of 'spindles' it contains.

The man or woman who has charge of a mule is called the 'minder. With mules of a certain size one or two assistants are required. The first assistant, whose age varies from fourteen to twenty years, is called the 'big piecer'; the second assistant, whose age varies from ten to fourteen years, is called the 'little piecer' or the 'creeler.' These assistants may be regarded as apprentices, and in course of time the 'little piecer' is promoted to be a 'big piecer,' and the 'big piecer' to be a 'minder.' It must not be forgotten that the employer as regards wages deals with the minder only, and does not directly pay the assistants. They are paid by the minder, and, though as a rule the assistants receive a certain definite proportion of the minder's wages, the minder may have to pay more or less according to circumstances; if, for instance, there be a scarcity of hands, he will have to pay more than the average. The new Bolton list stipulates that when spinning 30's or below, the employer is, as a rule, to pay a creeler.

The word 'price' is used as the equivalent of 'rate of wages.' The lists are called lists of prices. The word 'discount' is used in the sense of a reduction in the rate of wages.

The normal duty of the minder is to watch the mule when actually in motion, and to join all broken threads, but his duties are defined indirectly by specifying the payments he is to receive for work incidental to the normal duty of attending the mule when spinning.

The chief function of the lists is to specify what he is to receive for his normal duty, and to define the extra duties and the rate of payment.

The chief extra duties are—

'Stripping' or 'breaking out,' *i.e.*, taking the bobbins on which the sliver or unspun cotton is wound off the mule.

'Tubing,' or the inserting a small tube on the spindle with the object of preventing the thread at the end becoming entangled.

'Turning strings,' *i.e.*, altering certain strings so as to spin in the reverse direction.

'Starching' the end of the cop, so as to stiffen it, and thus prevent the end becoming entangled. This is not always paid as an extra, *e.g.*, in the Oldham list. 'Carrying bobbins' to and from the mule where a special carrier is not provided.

Principles on which the Lists are Based.

(1) *The amount of the yarn actually spun.*—In all the lists except the Oldham and Bolton lists, this amount is estimated by weight, and the wages are calculated at so much per 100 lbs.

In Oldham the amount is calculated by length, and an indicator fixed to the mule registers each yard of yarn spun.

In Bolton the payment is per 1,000 hanks.

Indirectly it may be said that payment by weight is the same thing as payment by length, inasmuch as 100 lbs. of yarn of a given fineness ought to be a fixed length. For instance, 100 lbs. of 30's means that in the 100 lbs. there are 30×100 hanks or lengths of 840 yards.

It has, however, been urged that actual measurement is the only true test of length, and that under the Oldham system every yard spun is registered, whereas under the other system a mistake may be made as to the fineness, and therefore weight is not an accurate test of length.

(2) *The number of spindles on the mule.*—As the number of spindles *increases* the rate of wages per 100 lbs. of yarn spun *decreases*. This rule has

been adopted on the principle that the advantage arising from the use of large mules should not be appropriated solely by either the employer or employed, but be divided between both parties. The extra amount of yarn spun gives an increased wage to the minder; the lower rate of wages gives a share to the employer.

(3) *The fineness of the yarn.*—The spinning of the coarser yarns is paid at a less rate than the finer yarns. The fineness of yarn is denoted by the number of hanks or lengths of 840 yards in 1 lb. For instance, 32's (*i.e.*, 32 hanks) means 32 hanks to the 1 lb.

A certain fineness being taken as the standard, the rate of wages per 100 lbs. increases as the fineness increases. Were such a principle not adopted, the minder spinning fine yarns would not earn as much wages as the minder spinning coarse yarns. To spin 100 lbs. of fine yarn requires a much longer time than to spin the same quantity of coarse yarn; and it is said that under the Oldham and other similar lists, applying to one-half the spinning trade, fine spinners earn less than the coarse spinners.

(4) *The number of turns.*—The length of yarn that can be spun in a given time by the minder varies, not only according to the fineness, but according to the amount of twist in the thread, because the greater the number of turns each inch of yarn receives, the shorter will be the total length. Two minders spinning yarn of the same fineness but with different number of 'twists' per inch would earn different wages. To equalise wages the number of twists must be taken into account.

It is evident that the amount of twist in a thread may be infinitely varied, and in order to avoid difficulties arising on this point the lists adopt a principle known as Scott's rule, for calculating the standard turns for any count of yarn. The rule is this: Multiply the square root of the count by 3·25 for weft, and 3·75 for twist, and you obtain the standard turns for that count. Extra turns are usually paid for by allowing two-thirds of the proportion.

The lists are therefore characterised by the following principles:—

(1) Wages depend on the amount of the produce.

(2) All advantage arising from improved machinery is divided between employer and employed.

(3) An equality is maintained between those spinning fine and coarse yarns, except in so far as the former require greater skill.

(4) Any extra work not coming within the normal duties of the minder is paid for separately.

The following analysis of the lists will show the method in which these principles are carried into practice:—

Analysis of Variations.

1. *Weft and Twist Standards.*

a. Weft.

	s.	d.					
Blackburn .	0	35·5	per 100 lbs. of .	30's	on Mules	from 631–649	spindles
,, .	0	41·5	,, ,,	32's	,,	,,	,,
Burnley .	0	42·75	,, ,,	,,	,,	640	,,
Preston .	0	42·75	,, ,,	,,	,,	,,	,,
Bolton .	0	18·56	per 1,000 hanks of	50's	,,	420	,,
Stockport .	0	16·00	,, ,,	30's	,,	360	,,
Hyde . .	0	14·66	,, ,,	36's	,,	660	,,
Ashton .	1	4⅛	,, ,,	,,	,,	360	,,

b. Twist.

	s. d.				
Blackburn	0 42·00	per 100 lbs. of	30's	on Mules from	531-540 spindles
Burnley	0 46·25	,, ,,	,,	,,	540 ,,
Preston	0 46·25	,, ,,	,,	,,	,, ,,
Bolton	0 21·04	per 1,000 hanks of	50's	,,	420 ,,
Stockport	0 17·00	,, ,,	30's	,,	360 ,,
Hyde	0 14·81	,, ,,	32's	,,	660 ,,
Ashton	1 5½	,, ,,	36's	,,	360 ,,

2. *Variation for Number of Spindles.*

As the number of spindles on a mule increases, the greater the amount of yarn spun per week, and therefore the more wages will be earned by the minder. It is evident that if the operative be paid at the same rate per pound or per hank on a large mule as on a small one, the only advantage gained by the employer would lie in the fact that the cost of a large mule would be something less per spindle than the cost of a small mule. This advantage, it is found, is not sufficient to encourage employers to improve or lengthen their machinery, and it is characteristic of the cotton lists that they divide the advantage arising from the greater number of spindles on a mule between the employer and employed. Hence the wages per pound or per hank decrease with every increase in the number of spindles. Profits and wages both rise with an increase in the number of spindles on a mule, other things remaining the same. It must be remembered, in working out the details of this division of the extra advantage, that as the mule increases in length additional assistants may be required, who have to be paid out of the wages of the minder. The number of persons required at a mule averages as follows:—

Up to 450 spindles	a man and a boy.
Over 450 ,, and under 750 spindles	,, ,,
,, 750 ,, ,, 1,200 ,,	,, 2 boys.
,, 1,200 ,,	,, 3 ,,

The variation per spindle is not the same under the different lists. The following table shows the various rules in force, W. indicating weft mules, and T. twist mules:—

Blackburn . . . . . Standard 631–640 spindles W., or 531–540 spindles T.
Add ¼*d.* for every 10 spindles below 630 W., or 531 T.
Deduct ⅛*d.* ,, ,, from 640–800 W., or 540–640 T.
,, $\frac{1}{16}$*d.* ,, ,, ,, 800–900 W., or 800–900 T.

Burnley } . . . . . Standard, 640 spindles W.; 540 spindles T.
Preston } Add ½*d.* for every 20 spindles below 600 W., or 500 T.
Deduct ¼*d.* ,, ,, above 600 W., or 500 T.

In Burnley list no deduction to be made after 800 spindles in counts below 24's.

Bolton . . . . . . Standard . 420 spindles W. and T.
Deduct ½ % for every 12 spindles above 420 spindles W. and T.

Stockport . . . . . . Standard . 360 spindles W. and T.
Deduct 6 % for every 12 spindles from 360–600 spindles W. and T.
,, 4 % ,, ,, 600–840 ,,
,, 3 % ,, ,, 840–1,044 ,,

Ashton . . . . . . Standard . 360 spindles W. and T.
Add ⅛*d.* for every 12 spindles below 360 spindles W. and T.
Deduct ⅛*d.* ,, 12 ,, up to 720 ,, ,,
,, ⅛*d.* ,, 24 ,, ,, 720–864 ,, ,,
,, ⅛*d.* ,, 48 ,, ,, 864–1,200 ,, ,,

3. *Variation for Fineness.*

As a rule, a mule will in a given time spin the same *length* of yarn whether the yarn be coarse or fine, but the *weight* of the yarn spun in a

given time depends mainly on its fineness. Yarn can be spun so fine that it takes 150 miles of it to weigh one pound. Whenever wages are paid by the weight of the yarn it is necessary to increase the rate per pound, if the necessary equality is to be maintained between the wages of the operatives. Such increase does not necessarily diminish the profits of the employer, as the finer the yarn the higher the price realised in the market. The allowance for fineness may therefore be regarded as a sharing by the operative in the increased value of the produce, and corresponds to some extent to the allowance given by the sliding scales in the coal industry in respect of a rise in the value of coal.

Fineness is technically indicated by reference to the number of yards in one pound. A hank is a length of 840 yards, and the number of hanks in one pound indicates the fineness. For example, 32's (*i.e.*, 32 hanks) means a yarn of such a degree of fineness that there are 32 hanks, or 32×840 yards, in one pound.

In the Oldham list wages are paid, not by the weight, but by the length of the yarn spun, and therefore it is unnecessary to make any allowance for fineness.

The following tables show the variation for fineness under the different lists. The leading principle is that the wages vary in proportion to fineness, estimated by the number of hanks in a pound, but for the higher counts an extra allowance per centum is made.

1. *Weft.*

Blackburn		
From 14's to 20's	add in proportion to the counts	+ 1 % for each hank.
„ 20's to 24's	„ „	„
„ 24's to 30's	„ „	„
„ 30's to 34's	the standard.	
„ 34's to 40's	„	
40's	„	+ 7½ %.
Over 40's	„	+ 6 % for every 5 hanks.
Burnley & Preston		
From 14's to 18's	add in proportion to counts	+ 1 % for each hank.
„ 20's to 23's	„ „	„
„ 24's to 30's	„ „	„
„ 32's	the standard.	
„ 34's to 70's	add in proportion to counts	+ 2 % for each 2 hanks.
Over 70's	„ „	+ 2½ % for each 2 hanks.
Bolton		
From 48's to 32's	deduct about	2 % for every 2 hanks.
„ 50's	the standard.	
„ 50's	add about	2 % for every 2 hanks.
Hyde		
From 10's to 20's	add	2 % for every 2 hanks.
„ 22's to 36's	the standard.	
„ 38's to 44's	add	2·4 % for every 2 hanks.
Over 44's	add	2·45 % for every 2 hanks
Stockport		
From 10's to 16's	add	3 % for every 2 hanks.
„ 16's to 24's	add	2¼ % for every 2 hanks.
„ 24's to 30's	the standard.	
„ 30's to 50's	add	2¼ % for every 2 hanks.
Ashton		
From 34's 30's to	deduct	¼*d.* for every 2 hanks.
„ 36's	the standard.	
„ 40's	add	$\frac{6}{8}$*d.*
„ 45's to 55's	add	1*d.* for every 5 hanks.
„ 55's to 65's	add	⅞*d.* for every 5 hanks.
„ 65's to 100's	add	⅝*d.* for every 5 hanks.

2. Twist.

Blackburn		
From 14's to 20's . .	in proportion	+ 1 % for each hank.
,, 20's to 24's . .	,, ...	+ ½ % ,,
,, 24's to 30's . .	,, ...	− 5 %. ,,
,, 30's . .	the standard.	
,, 32's to 36's . .	in proportion	+ 7½ %.
Above 36's . .	,, ...	+ 9 % for every 6 hanks.
Burnley		
From 14's to 18's . .	in proportion	+ 1 % for each hank.
,, 20's to 22's . .	,, ...	+ ½ % ,,
,, 24's to 28's . .	,, ...	− 1½ % ,,
,, 30's . .	the standard.	
,, 32's to 36's . .	in proportion	+ 2 % for every 2 hanks.
,, 38's to 60's . .	,, ...	+ 3% ,,
Preston	same as Burnley, beginning at 24's.	
Bolton[1]		
From 48's to 32's . .	deduct 1 % for every 2 hanks.	
,, 50's . .	the standard.	
Over 50's . .	add 2 % for every 2 hanks.	
Hyde	same as for weft.	
Stockport	,,	
Ashton		
From 30's to 34's . .	deduct ¼*d.* for every 2 hanks.	
,, 36 . .	the standard.	
,, 40's . .	add ¾*d.*	
,, 45's to 50's . .	add 1⅛*d.* for every 5 hanks.	
,, 55's to 65's . .	add 1*d.* ,,	

4. *Variation for Turns.*

The length of yarn spun in a given time depends not only on the fineness, but on the number of turns given to the thread by the machinery. Hence a standard has been adopted which regulates the number of turns to be given per inch for each count of yarn. Any variation in the number of turns necessitates a variation in wages; the more turns put in the greater the rate of wages. The principle is the same as that which underlies the extra allowance for the fine yarns. The more turns the less yarn spun in a given time.

The usual rule adopted is this: Multiply the square root of the count by 3·75 for twist, and 3·25 for weft, but in the new Bolton list the rule is: Multiply the square root of the counts by 3·606 for twist, 3·394 for reeled yarn, and 3·186 for weft.

Extra Allowances.

(*a*) *Spinning weft on twist mules.*—

	Extra allowance
Blackburn .	3 % unless spun in large cops.
Burnley .	5 % except when speed of spindle is equal to speed of weft spindles of same mill on the same counts. In the latter case the Ashton list allows 3 % extra.
Preston . .	(as above)
Bury . . .	(as above)
Ashton . .	(as above)

(*b*) *Turning strings.*—The spindles usually revolve from right to left. Sometimes it is desirable to spin by making them revolve from left to right, and then it is necessary to alter the strings which make the spindles revolve.

[1] See table in new list.

The allowance allowed by some of the lists is as follows:—

Ashton . .	Average wages that would otherwise have been earned.
Hyde . .	$2\frac{1}{2}d.$ per 100 spindles.
Bolton . .	$2s.\ 0\frac{3}{4}d.$ for 600 spindles or under, with $2\frac{1}{4}d.$ for every 50 spindles additional

(c) *Resetting mules, &c.*—When the machinery is being repaired the presence of the minder is necessary, owing to his special knowledge of the mule. For his assistance on such occasions he is paid:—

			£	s.	d.
Under Blackburn list		. . . .	0	3	0 a day.
„ Bolton „		21s. per week if both mules stopped; if one mule only stopped, 30s. per week, but no payment for yarn spun			
„ Ashton „		. . . .	1	1	0 per week.
„ Oldham „		. . . .	0	0	5 an hour.
„ „ „		mules from 57–76 doz. . .	0	0	$5\frac{1}{2}$ „
„ „ „		larger mules	0	0	6 „

If the piecer be also employed he is paid by the employer.

(d) *Renewals.*—A renewal is to be distinguished from a resetting. The latter refers to the overhauling of the entire mule; the former means a temporary stoppage by the overseer in order to replace some particular part of the mule.

The Blackburn and Bolton lists provide that the minder is to be paid, if required, the same rate as for resetting, provided the stoppage be for $2\frac{1}{2}$ hours.

(e) *Stripping.*—'Stripping,' or 'breaking out,' means taking the bobbins with a certain kind of cotton off the mule in order to replace them with bobbins of another kind of cotton, so as to spin a different quality or fineness of yarn.

The Blackburn, Burnley, Preston, and Bury lists allow 1*s.* 6*d.* for a mule containing 400 to 500 rovings in each wheel, and for every 100 rovings above 500, 6*d.* per 100 extra. The Preston and Bury lists provide for stripping wheels containing under 400 rovings, and allow 1*s.* 3*d.* The Ashton and Stockport lists allow 2*d.*, and the Hyde list $2\frac{1}{2}d.$, for every 100 bobbins; whilst the Bolton list allows at the rate of 3*s.* 3*d.* per 600 spindles or under, with 3*d.* for every additional 50 spindles.

(f) *Tubing.*—Tubing means the placing of a tube on the spindle on which the yarn is spun.

The Blackburn and Preston lists allow 4*d.* for every 100 lbs. of weft and 2*d.* for every 100 lbs. of twist for tubing with the apparatus.

For tubing by the hand the Preston list allows 6*d.* a doffing.

The Bury list has no rule.

The Hyde and Stockport pay for tubing according to the weight of the yarn. The former list allows 8*d.* per 100 lbs. weft, and 6*d.* per 100 lbs. twist; the latter 4*d.* per 100 lbs. weft, and 2*d.* per 100 lbs. twist.

For tubing pin cops.—The Burnley list allows one-eighth of a penny per set per lb. weight of such set when spinning 60's to 100's, with a penny per set added for every 10 hanks finer than 100's, and a reduction of one halfpenny per set for every 10 hanks when spinning 60's to 20's.

For large cops the amount allowed depends on the counts and number of spindles.

(g) *Starching.*—When the yarn is not spun on tubes it is necessary, in order to prevent the thread at the end of the cop from becoming loose or

being injured after the cop is taken off the spindle, to apply a certain amount of starch.

The allowance for starching is as follows:—

	Weft	Twist
Blackburn	2*d.*	1*d.* per 100 lbs.
Hyde	1*d.*	$0\frac{1}{2}d.$ „
Stockport	2*d.*	1*d.* „
Bury	2*d.*	1*d.* „

(*h*) *Cop and bobbin carrier.*—The cops or bobbins require to be taken off the mule and carried to the warehouse. If such duty falls on the minder he is entitled to extra pay as follows:—

Ashton	$\frac{1}{2}d.$ per 1,000 hanks—*i.e.*, $\frac{1}{4}d.$ for cop-carrier and $\frac{1}{4}d.$ for bobbin-carrier
Oldham	$1\frac{1}{2}d.$ per 100 lbs. 1*d.* per 1,000 lbs. if hoist be used.
Bury	$1\frac{1}{2}d.$ per 1,000 hanks

In the new Bolton list the extra payment is determined by the committees of the two associations.

The New Bolton List.

The new Bolton list has been issued so recently that it has been impossible to give it the detailed examination it requires. No other list except the Oldham list contains so many details, or so carefully defines the extra allowances, and it even goes so far as to specify what days are to be recognised as holidays.

The Oldham List.

The Oldham list differs in several important points from the lists in other parts of Lancashire. It is based on payment according to the actual length of yarn spun as measured by a self-acting indicator affixed to the mule. The standard wage is not a fixed amount per 100 lbs., but a certain normal weekly wage varying with the number of spindles on the mule. This normal wage is supposed to be the amount that could be earned in a normal week, the mules running at a normal speed. For instance, the normal wages per week for a mule containing 100 dozen spindles is 3*l.* 9*s.* 2*d.*, which is supposed to be earned in a normal week of 3,230 minutes, the mule running at a normal rate of three draws of 63 inches in every 50 seconds.

It is further implied—

(*a*) That the mule is a self-acting mule—*i.e.*, the list does not apply to double-decked mules, odd mules, three mules, or hand mules.

(*b*) That the cotton used is of an average quality—*i.e.*, that it is neither of a low quality nor of a superior quality.

As a rule, the minder will earn the normal wages; but if he neglects his work or is idle, the amount he will spin in a week will be less than the normal amount, and he is paid less accordingly.

Two advantages are claimed for the Oldham list as compared with the other lists: (1) that payment by length is more equitable to the operatives than payment by weight, as no mistake is possible as to the amount of yarn produced. Payment by weight without regard to fineness would, as has been pointed out, have this serious result, that the minder who was spinning fine yarns would receive less wages than he who was spinning coarse yarns; for, though both would spin the same

amount in length in a given time, assuming the turns per inch to be the same, the difference in weight would be very great. Hence where payment is by weight, the rate of wages increases with the number of counts or fineness. There are no indicators to register the fineness of the yarn, and if any mistake be made the operative may suffer. On the other hand, where payment is by length, no mistake is possible, and the indicator by registering the length indirectly registers the fineness of the yarn.

(2) The second advantage claimed for the Oldham list is that it divides the advantage resulting from an increased speed with the employer. The employer is therefore interested in improving his machinery. It is said that this principle has been one of the causes that has led to the development of the Oldham spinning trade. An employer evidently has no motive to adopt new and improved methods if the whole of the advantage is reaped by the operatives. Recognising this, the Oldham employers and employed have adopted the equitable rule of dividing the advantage between them. The same principle is found in all the lists as regards the advantage resulting from an increase in the number of spindles; but it is claimed that the Oldham list is the only one that adopts the principle in regard to speed.

(*a*) *The normal week.*—The normal week is not an absolutely fixed time. An allowance is made for the necessary time that the mule is at rest. The first allowance is for cleaning and accidental stoppages: for this the allowance is $1\frac{1}{2}$ hours. The second allowance is for doffing, that is, for taking the cops off the spindles, and varies with the size of the mule. For mules of sixty dozen of spindles, it is 5 minutes; of over sixty dozen and under ninety dozen, 6 minutes, and above ninety dozen, 7 minutes for each doffing. Suppose, for instance, that the cops are removed ten times in a week from a mule of 100 dozen of spindles, the allowance of time would be 70 minutes. These new classes of allowances are deducted from the maximum working week of $56\frac{1}{2}$ hours, and the result is the average time a mule will run during a week.

(*b*) *The draw.*—Each time that the head of the mule moves outwards and returns, a certain fixed length of yarn is spun—*e.g.*, 63 or more inches. The total amount of yarn spun in a given time evidently depends on the number of times the head moves outwards and returns. The Oldham list takes as a standard speed three draws or movements of 63 inches in length every 50 seconds. The amount of yarn spun in 50 seconds will be 63×3 inches on each spindle, as the length of 63 inches is constant and as the speed is always calculated with reference to the number of seconds required for three draws.

The quicker the speed the greater the amount of yarn spun, and therefore in the absence of any special rule the greater the amount of wages. Under such circumstances the employer would derive no advantage except in so far as he was enabled to place a greater supply on the market. From one point of view he would be under a positive disadvantage, as the quicker speed would wear out the machinery in a shorter time than otherwise would be the case. The Oldham list recognises that the employer should share with the employed in the advantage resulting from increased speed, and divides the advantage equally between them. A table will be found in the list in which this allowance has been worked out in detail, and which is based on the principle that for every second less than the standard number, 50, taken by the mule head to move three times, a certain amount is to be added to the weekly wages, varying with the

number of spindles. For instance, on a mule of 100 dozen spindles $8\frac{1}{4}d.$ is allowed for every second.

Extra Allowances.

Breakage.—$2\frac{1}{2}$ per cent. is allowed for breakage, but the self-acting indicator is so constructed as to make this allowance.

Fineness.—As the Oldham list pays by length, and not by weight, it is not necessary, as a rule, to take the fineness of the yarn into account, as a mule will in a week spin the same length of fine yarn as of coarse yarn, assuming the turns per inch to be the same.

An exception is made in the case of 24's, and under, where an extra allowance is made.

Bobbin carrier.—If a bobbin carrier is not provided $1\frac{1}{2}d.$ per 100 lbs. of yarn extra is allowed; if a hoist for carrying the bobbins to another room is provided but no carrier then $1d.$ per 100 lbs. is the allowance.

How Wages are Calculated.

The calculation to be gone through may be thrown into the following general formula :—

Let W=normal wages per week.
a=allowance for speed.
x=extra allowances.

Then $W+a+x$=normal wages per week.

Let S=number of spindles.
d=number of seconds in which three draws occur of 63 inches in length.
m=number of seconds in a normal working week.
K=number of inches in a bank.
H=number of hanks spun in a normal week from one mule.
I=amount actually spun, as shown by indicator.

Then

$$\frac{S \times 63 \times 3}{d} = \text{amount spun in a second.}$$

$$\frac{S \times 63 \times 3}{d} \times m = \text{amount in inches spun in a normal week.}$$

$$\frac{S \times 63 \times 3}{d} \times m \times \frac{I}{K} = \text{number of hanks that could be spun in normal}$$

week $=H$.

Deduct $2\frac{1}{2}$ per cent. for breakages :

$$H - \frac{5H}{200} = \text{number of hanks allowing for breakages.}$$

And since $W+a+x$=normal wages,

$$\frac{W+a+x}{H - \frac{5H}{200}} = \text{rate (R) per hank that is to be paid for the actual amount}$$

spun.

$R \times I$ gives the wages payable.

An actual illustration may be given. Suppose a mule of 100 dozen of spindles (1,200) to be spinning 32's, and running 3 draws of 63 inches in 45 seconds, the number of doffings being 10 in the week:

W=£3 9*s.* 2*d.*

a=3*s.* 5*d.*, as the list gives an allowance of $8\frac{1}{4}d.$ for every second on mules of 100 spindles.

x=2*s.* 6*d.*, assuming no bobbin-carrier is employed, as will appear lower down.

$\therefore$ W+a+x=3*l.* 15*s.* 1*d.*

S=the number of spindles—*i.e.*, 200.

d=45 seconds.

m=3,230 seconds.

From $56\frac{1}{2}$ hours deduct the usual $1\frac{1}{2}$ hours for cleaning. For the 10 doffings deduct 7 minutes per doffing according to the list, and the result is the normal week given above.

$56\frac{1}{2}-1\frac{1}{2}-\frac{70}{60}=3230$ seconds.

K=840×12×3.

There are 840 yards in a hank.

Then $\dfrac{1200\times63\times3}{45}\times3230\times\dfrac{1}{840\times12\times3}=32300.$

$\therefore$ 32300×2=64600, or the number of hanks spun from a pair of mules in a normal week.

$\dfrac{64600}{32}=2018=$ number of lbs. spun in normal week from which the allowance for bobbin carrier is calculated at the rate of $1\frac{1}{2}d.$ per 100 lbs.

From 64600 deduct $2\frac{1}{2}$ per cent. for breakages. This leaves 62985; and $\dfrac{3l.\ 15s.\ 1d.}{62985}=14{\cdot}30d.$, or the rate per hank to be paid for the actual amount spun.

The actual amount spun is shown by the indicator, and this multiplied by 14·30*d.* gives the wages paid to the minder.

Variation of Wages under Oldham List.

Oct. 22, 1877	. . .	5 per cent. reduction
May 27, 1878	. . .	5 ,, ,,
Nov. 25, 1878	. . .	5 ,, ,,
Oct. 20, 1879	. . .	5 ,, ,,
Feb. 9, 1880	. . .	5 ,, advance
Jan. 1881	. . .	5 ,, ,,

Origin of the Lists.

The first list known in the spinning trade was that adopted at Preston in 1859. Mr. Banks, of Preston, who has been a member of the Cotton Spinners' Association for over fifty years, gives the following account of the origin of the list:—

'As far back as 1836 I remember that every mill had its own list of wages based on a certain sum per 1,000 draws, say, for 36 weft, 660 spindles, 2*s.*, the working day being 12 hours, 25 000 to 25,500 draws a week being produced. In 1859 there was a strike at Simpson's Park

Lane Mills, where wages were lower than at any other mill in the town. The result of the strike was to raise the wages at these mills. And the first list was then formed, being based on the average paid in the town. This did not prove satisfactory and another list was made in 1866 based on the average of eleven districts, and turned out to be a great advance on the former list, giving in many cases 15*s*. a head increase.'

This view of the origin of the lists, viz., that they were based on the average wages paid in the districts in which they were adopted, is borne out by the evidence of those concerned in drawing them up. Their subsequent development is marked chiefly by (1) the gradual definition of the normal duties of the minder by specifying the allowances he is entitled to for extra duties, (2) the working out of the principles in detail, and (3) the formation of the Oldham list.

Effects of the Lists.

The lists have not succeeded in removing all probability of dispute between employer and employed. They have, it is true, introduced uniformity into the payment of wages in the cotton trade, caused wages to be payable on definite and known principles, adjusted the wages of different classes of spinners, and defined strictly the duties of the operative; but they do not make wages vary either with the varying cost of the raw material or the varying prices realised for the finished product. The standard, in other words, implies a given condition of trade. A changed condition, *e.g.*, a rise or fall in the price of yarn, when fully established results in a percentage being added to or taken from the wages payable. The method of determining the occasion and the amount of alteration is determined by negotiation between the association of employers and the association of spinners. Strange to say, the lists do not provide that such an important matter should be referred to arbitration in case an agreement cannot be arrived at; but the new Bolton list, issued only a few weeks ago, does contain a provision that matters in dispute shall be referred to a joint committee. It is difficult to see how the price either of the raw material or of the yarn could be taken into account without making the lists exceedingly complex, and as they now stand they are necessarily anything but simple. To ascertain the prices given or realised would entail a great amount of labour, and as far as can be ascertained no such proposal to add these additional elements to the lists has been made by either the employer or employed.

The Committee desire to express their thanks to those gentlemen who have assisted so ably in furnishing materials for the reports. They are specially indebted to Mr. J. Mawdsley, Secretary of the Amalgamated Association of Operative Cotton Spinners; Mr. T. Birtwistle, Secretary of the Weavers' Association; Mr. J. C. Fielden, of Manchester; and Mr. J. T. Fielding, of Bolton.

WEAVING.

The Committee have been able to secure twenty-two lists that have been or are now in force in the weaving industry. Of these lists the most important are the Blackburn list of 1853 for plain cloth, and the North and North-east Lancashire list of 1887 for fancy cloth. The Burnley,

Chorley, and Preston lists are based on the Blackburn list, and relate to a fine class of goods. The Hyde, Stockport, and Ashton lists have been gradually superseded by the Blackburn list as regards plain cloth. The Nelson satin list and the Chorley fancy list have been combined into the North and North-east Lancashire fancy list. The Oldham list relates to velvets and heavy goods.

The lists may therefore be divided into two classes: (1) those regulating wages for weaving plain cloth, and (2) those regulating wages for weaving fancy cloth. The Blackburn list may be taken as the type of the former, and the North and North-east Lancashire as the type of the latter class.

I. The Blackburn List for Plain Cloth.

The Blackburn list was framed in 1853, and was based on the average wages paid by different firms at that time. The leading principles of the original list are still followed, but the application of the list has in the course of years been worked out in detail. A distinction is drawn between the work of attending the loom whilst the cloth is being woven, and work incident to weaving but not forming part of the normal duties of the weaver.

i. The Standard.

The standard wages is $12\cdot25d.$ for weaving $37\frac{1}{2}$ yards of cloth, of from 36 to 41 inches wide, containing 16 threads or picks of weft in the $\frac{1}{4}$ inch in a loom of 40 inches wide, using a reed which contains 60 threads or ends of twist in the inch, the materials used being 30's to 60's weft and 28's to 45's twist.

Examining this standard it will be found that all the elements may be brought under four heads:—

(1) The fineness of the yarn or materials.
(2) The closeness of the threads.
(3) The width of the cloth.
(4) The length of the cloth.

No regard is had, as in the sliding scale, to the price the manufacturer will receive for the cloth, except in so far as any one or all of these elements affect the price that the cloth will realise. The price is taken into account in another way, viz., by the operatives obtaining an addition to, or the employers enforcing a reduction of, so much per cent. owing to increased or lower prices being received.

The following table shows the actual course of wages since the list was adopted:—

Aug. 17, 1853, list adopted.	
Aug. 19, 1853, advance on list	10 per cent.
May 19, 1854, return to list.	
Mar. 10, 1860, advance	5 per cent.
Feb. 7, 1861, return to list.	
April 15, 1867, list revised.	
May 6, 1869, reduction on list	5 per cent.
July 28, 1870, return to list.	
June 19, 1878, reduction (after strike) . .	10 per cent.
April 2, 1879, reduction	15 per cent.
1881, advance of 5 per cent., leaving wages 10 per cent. under list.	

There can be no doubt that the want of dependence between the wages paid and the price realised is one disadvantage of the list as compared

with the sliding scale. It would, however, be extremely difficult to take the price of the product into account, more especially as the manufacturer is always liable to be affected by the ever-varying cost of the raw material. In the coal trade the cost of the raw material, viz., the coal, is practically constant, as it is governed by a lease made for a long period of time, whereas the supply, and therefore the price of cotton, depends on ever-varying conditions.

ii. Variations.

The important practical use of the list is that it adjusts the wages of operatives engaged in weaving different kinds of cloths, of varying degrees of fineness, widths, and lengths.

1. *Fineness of the Materials.*

The fineness of the materials used, *i.e.*, the twist and the weft, bears closely on the fineness of the cloth. The finer the reed through which the warp passes, the greater the number of ends or threads to be watched, and the greater the number of breakages of the threads. More skill is therefore required to attend a loom weaving fine cloth than one weaving a coarser cloth. By skill is meant mental skill and manual dexterity rather than bodily labour, though the actual number of bodily operations tends to increase with the fineness of the yarn used.

The weaving of the coarser yarns involves greater bodily labour though not greater skill, and such increased labour is paid at a higher rate though less wages may be earned. Hence the *rate* of wages increases as the materials become (*a*) finer, or (*b*) coarser.

The fineness of the materials is indicated by the number of lengths of 840 yards, *i.e.*, hanks required to weigh 1 lb., *e.g.*, 30's means yarn of which 30 lengths of 840 yards weigh 1 lb.

The standard yarn is yarn from 30's to 60's weft and 28's to 45's twist. Such yarn is regarded as medium. For yarns of other degrees of fineness the allowance is as follows:—

Weft.

14's and under 16's add 10 per cent.
16's „ „ 20's „ 8 „
20's „ „ 26's „ 5 „
26's „ „ 30's „ 2 „
30's to 60's standard.
Above 60's add 1 per cent. for every 10 hanks.

Twist.

14's and under 20's add 2 per cent.
20's „ „ 28's „ 1 „
28's to 45's standard.
Above 45's and under 60's add $1\frac{1}{2}$ per cent.
Above 60's „ 1 „ for every 10 hanks.

Closely connected with fineness is the closeness of the threads in the cloth. The more threads in an inch of cloth the more work there is to be done by the weaver, and where fine yarn is employed the greater skill is required. In regulating the variations for closeness the lists distinguish between the warp or twist and the weft.

2. *Closeness of the Threads.*

The warp or twist is drawn through what are known as a set of gears, comprising healds and reeds. The healds have loops through which each thread passes, each thread occupying a separate loop. The threads then pass through the reed, which is divided into spaces, two threads as a rule passing through each space, though in certain special classes of cloth one to six threads may pass through together.

The closeness of the warp depends on the number of threads or ends in an inch. In the Blackburn and Burnley lists a '60 reed,' *i.e.*, a reed containing 60 threads or ends in every inch, is the standard.

When a coarser reed is used the Blackburn list deducts $\frac{3}{4}$ per cent. for every two ends or counts down to 48, but below 48 no deduction is made. The Burnley list allows a similar deduction down to 52, no deduction being made for reeds below that size.

When finer reeds are used $\frac{3}{4}$ per cent. is added for every two ends or counts above 60, but in the Burnley list the addition is 1 per cent. for every two ends or counts above 68.

Weft.

The closeness of the weft which is driven by means of a shuttle between the warp can be calculated in two ways, either by actually counting the number of threads in a $\frac{1}{4}$ inch or by a formula based on the sizes of the wheels and beams in the loom. Both methods ought to give the same result, as the looms are so constructed that they can be made to weave cloth of any degree of closeness. A single thread of the weft is called a 'pick' or 'shot,' and the Blackburn list takes as a standard 16 picks to the $\frac{1}{4}$ inch.

The formula referred to above is as follows:—

Let r = number of teeth in the rack wheel
s = " stud "
b = " beam "
p = " little pinion wheel
c = circumference of emery beam
w = number of teeth in change wheel

Then $$\frac{r \times s \times b}{p \times 4c} = \text{mathematical dividend (M).}$$

To this add $1\frac{1}{2}$ per cent., so as to allow for contraction of the cloth between the loom and the counter.

$$M + \frac{M}{80} = \text{practical dividend (P).}$$

$$\frac{P}{W} = \text{number of picks per } \tfrac{1}{4} \text{ inch.}$$

Of the various wheels referred to above the only one that is varied in a loom so as to vary the closeness of the weft is W, which is called the change wheel. The other wheels are constant, and, therefore, for a given loom the dividend is constant. In the Blackburn list will be found the dividends for the various makes of looms found in North-east Lancashire, and hence the only other element required in order to calculate the number of picks per $\frac{1}{4}$ inch is the size of the change wheel.

The variation for picks is reckoned as follows: 16 picks to the $\frac{1}{4}$ inch are taken as the standard. For cloth containing over 8 and up to 18 picks wages vary in proportion to the number of picks, but in the case of cloth containing fewer than 8 or more than 18 picks to the $\frac{1}{4}$ inch 1 per cent. is allowed for every pick over and above the proportionate difference in the number of picks. This extra allowance is said to be in respect of the higher skill and increased labour required from the operative.

3. *Width of the Cloth.*

The wider the cloth the higher the rate of wages, as the more skill and labour are required. A 40-inch loom with 45-inch reed space is taken as the standard. For looms of a narrower width 1 per cent. per inch is deducted down to 30 inches; below 30 inches and down to 26 inches $\frac{5}{8}$ per cent. per inch is deducted. Above 40 inches 1 per cent. per inch is added up to 45 inches, and above 45 inches 2 per cent. per inch is added. Strict rules are laid down prescribing the width of cloth to be woven in a loom of a given width. For instance, a 30-inch loom is supposed to weave cloth from 27 to 31 inches; a 40-inch loom, cloth from 36 to 41 inches, and so on [see Blackburn list].

Sometimes it may be necessary to depart from this principle, and to weave narrow cloth in a broad loom. In such case you deduct from the wages payable for weaving the prescribed width on such broad loom half the difference between such wages and the wages payable for weaving the narrow cloth on its prescribed loom. For instance, if cloth 27 to 31 inches (which ought to be woven on a 30-inch loom) is woven on a 40-inch loom, you deduct from the wages payable for a 40-inch loom one-half the difference between such wages and the wages payable on a 30-inch loom.

4. *Length of the Cloth.*

$37\frac{1}{2}$ yards is the standard length of cloth. The list gives the rate for weaving various other lengths, including 100 yards, and hence the rate per yard can easily be calculated.

Order in which Allowances are to be made.

In calculating wages the allowances are to be made in the following order:—

(1) Allowance for reeds
(2) " materials
(3) " picks
(4) " widths.

Suppose it is desired to find the wages for weaving $37\frac{1}{2}$ yards (the standard length) 39 inches wide on a 40-inch loom (the proper loom for that width of cloth), 60 reed (the standard reed), 32's twist, 34's weft (these being standard counts), 35 change wheel, 507 dividend.

$$\frac{507}{35} = 14{\cdot}486, \text{ the number of picks.}$$

The tables give as the wages for one pick under the above conditions ·7656.

As 1 pick : 14·486 : : ·7656 : 11·0904816.

An ingenious method has been adopted for facilitating the calculation.

The standard length, as has been pointed out, is $37\frac{1}{2}$ yards, containing 16 picks per $\frac{1}{4}$ inch, for which the weaver is paid 12·25*d*., that is, at the rate of ·765625 per pick. Mr. Birtwistle has worked out the rate per pick for six different lengths, viz., $37\frac{1}{2}$, 24, 46, 58, 60, and 100 yards. The last-mentioned rate is most useful, as you can at once find the rate per pick of 1 yard and then calculate the wages for any number of yards. The wages for weaving $37\frac{1}{2}$ yards being thus known, the wages for any length of the same cloth can be easily calculated.

The next example illustrates the calculation where the fineness of the reed, the fineness of the materials, and the length to be woven vary from the standard.

Find the wages for weaving $23\frac{1}{2}$ yards of cloth 43 inches wide in a 45-inch loom (*i.e.*, the proper loom for this width of cloth), 96 reed, 60's twist, 80's weft, 21 change wheel, 609 dividend.

$$\frac{609}{21} = 29 \text{ picks.}$$

The tables do not give the rate per pick for $23\frac{1}{2}$ yards, but they give it for 100 yards of standard materials, viz., 2·4332. For one yard the rate would be ·024332. This, it will be seen, includes all allowance for the extra fineness of the reed.

·024332 × 29 × 23·5 yards = 16·582258, or the wages for weaving $23\frac{1}{2}$ yards of cloth containing 29 picks to the $\frac{1}{4}$ inch. We have now to allow for the variation (1) in materials, (2) in picks from the standard; viz., (1) $1\frac{1}{2}$ per cent. for twist and 2 per cent. for weft, *i.e.*, $3\frac{1}{2}$ per cent., and then (2) 11 per cent. for the extra picks.

	16·582258
add $3\frac{1}{2}$ per cent.	58037903
	17·16263703
add 11 per cent.	1·8878900733
	19·0505271033 wages.[1]

The next example illustrates the calculation where narrow cloth is woven in a broad loom.

Find the price for weaving 38 yards of cloth 35 inches wide in a 40-inch loom, 36 reed, 32's twist, 40's weft, 71 change wheel, 428 dividend.

$$\frac{428}{71} = 6{\cdot}028 \text{ picks.}$$

100 yards on 40-inch loom 48 reed	= 1·9498
" 35 "	= 1·8523
	2)3·8021
	1·90105

The rate per yard would be ·090105.

Then ·090105 × 6·028 picks × 38 yards = 4·35462. To this must be added 3 per cent. per pick.

4·35462
1306386
4·4852586 *d.*

[1] Present rate (1887) is 10 per cent. below this.

VARIETIES OF PLAIN CLOTH.

The Blackburn list, it will be found, makes provision for varieties ot cloth not properly called plain cloth. If the cloth has an ornamental coloured border it is called 'plain dhooty,' and for weaving this 10 per cent. extra is allowed. 'Dobbie dhooty's' mean cloths which have a raised or figured pattern, and for some of these from 20 to 50 per cent. extra is paid. 'Splits,' or cloth with a double salvage down the centre, are also specially provided for.

II. THE NORTH AND NORTH-EAST LANCASHIRE LIST FOR FANCY CLOTH.

This list, which has been widely adopted, regulates the wages paid for weaving various kinds of fancy cloth, such as brocades, damasks, stripes, satins. The principle adopted is to pay a certain percentage over that paid for plain cloth. Three classes of cloth are specially provided for:—

(1) Double lift Jacquards.
  Plain grounds, 30 per cent. extra.
  Satin grounds, 25 ,,
  Lace brocades, 5 ,,
(2) Dobbie and Tappet motions.
  The percentage varies with the number of staves.
(3) Satins, &c.
  Eight per cent. additional to be paid for cloth up to 25 picks, and for every additional pick $\frac{1}{2}$ per cent. extra.

These figures are sufficient to indicate the method adopted for fixing wages in the fancy cloth trade. An intimate knowledge of the weaving industry is necessary in order to understand the technical terms used, but for the purposes of this report it is only necessary to point out that the fancy list is based on the plain list, and that the extra wages is a recompense for a high degree of skill and for increased labour.

Third Report of the Committee, consisting of Professor BALFOUR STEWART (*Secretary*), Professor W. G. ADAMS, Mr. W. LANT CARPENTER, Mr. C. H. CARPMAEL, Mr. W. H. M. CHRISTIE (*Astronomer Royal*), Professor G. CHRYSTAL, Staff Commander CREAK, Professor G. H. DARWIN, Mr. WILLIAM ELLIS, Sir J. H. LEFROY, Professor S. J. PERRY, Professor SCHUSTER, Sir W. THOMSON, *and* Mr. G. M. WHIPPLE, *appointed for the purpose of considering the best means of Comparing and Reducing Magnetic Observations.* (*Drawn up by* Professor BALFOUR STEWART.)

[PLATES I. and II.]

SINCE their last report this Committee have met twice at 22 Albemarle Street, London, W.

At the first of these meetings, which took place on November 13, 1886, it was resolved that the establishment of regular magnetic observations at the Cape of Good Hope and in South America would materially contribute to our knowledge of terrestrial magnetism.

It was also resolved that it is desirable to determine if the luni-solar variation be dependent on the state of the sun's surface.

Regarding this resolution, the Secretary has quite recently received the following communication from Mr. C. Chambers: 'We are extending the general investigation, as our limited computing force admits, to other quarters, so that any variation with the sun-spot period will make itself apparent in due course, and I will give you early notice of the fact when any definite evidence becomes available.'

The last of these meetings took place on June 30, 1887. In this meeting it was resolved 'that in the opinion of this Committee the time has now arrived when steps should be taken to obtain with as little labour as possible sufficiently accurate values of the simultaneous solar-diurnal variations of the magnetic elements at various stations throughout the globe.'

It is hoped that the directors of the various observatories in which self-recording magnetographs are in action will join in this movement, and in order to leave them sufficient time for preparation it is proposed that a commencement be made on January 1, 1889. The Committee propose to confine their simultaneous comparison to certain selected days for which there are reasonably smooth registers at Greenwich or Kew. It is believed that these days will, in all probability, be of a similar character for the other stations; but in case there is slight disturbance at any station for any of the selected days this may be got rid of by the method pursued at Greenwich, where the practice has been to draw a pencil curve smoothing down the irregularities of the trace. Photographic records, or hourly measurements of these curves, smoothed when necessary, are desired by the Committee.

For this purpose it will be necessary to know the scale-coefficient for the three magnetographs, as well as the temperature-coefficient for the horizontal and vertical force magnetographs. It will likewise be necessary to have a sufficiently accurate record of the variation of temperature for each of the selected days at the self-recording chamber of each of the stations. The Committee would make the following suggestions as to the method of obtaining the scale and the temperature coefficients.

(1.) *Scale-coefficients.*

There can be no doubt about the scale-coefficient for the declination magnetograph.

The scale-coefficients for the two force magnetographs are determined by the method of deflections, for which suitable apparatus is provided for each observatory, and observations of deflection are made at two or more different distances of the deflectors. There is an absolute necessity for using two or more different distances in determining the scale-coefficient of the vertical force instrument, for we have here to prove that the knife-edge is sufficiently good; and the best way of doing this is to be sure that the scale-coefficient is the same both for small and for large departures as determined by means of deflections at two or more different distances of the deflectors.

It is desirable that the measurements of the horizontal and vertical forces should be expressed in terms of absolute value in C.G.S. units, and that the scale value ·0005 C.G.S. units for 1 centimètre be adopted for horizontal and vertical force instruments of the Kew pattern.

(2.) *Temperature-coefficients.*

In the opinion of this Committee the best method of determining the temperature-coefficients of the two force magnetographs is by alternately heating and cooling the magnetograph room, the former operation being conducted by means of a stove devoid of iron. Two sets of experiments are desirable, one in summer and one in winter. The Committee are likewise of opinion that it is necessary to obtain separate coefficients for ascending and descending temperatures, inasmuch as the behaviour of magnets with respect to temperature is not perfectly reversible.

More especially will this be necessary in the case of the Balance, or vertical force magnet, for if this has its temperature-coefficient partly corrected by means of a zinc bar the uncompensated portion may be very different for ascending and descending temperatures. The director of any observatory who is willing to co-operate with the Committee is requested to communicate with Professor W. G. Adams, King's College, London.

The Rev. S. J. Perry and Professor Stewart are continuing their comparison of simultaneous magnetic fluctuations at Kew and Stonyhurst.

Professor Schuster has recently communicated to the Royal Society a paper entitled 'Experiments on the Discharge of Electricity through Gases,' which bears upon the work of this Committee.

These experiments show 'that a steady current of electricity can be obtained in air from electrodes at the ordinary temperature, which are at a difference of potential of one-quarter of a volt only (and probably less), provided that an independent current is maintained in the same closed vessel.'

Professor Schuster makes likewise the following remark: 'I have last year obtained, by calculation, results which seem to show that the principal cause of the diurnal variation of terrestrial magnetism is to be looked for in the upper regions of the atmosphere. Professor Balfour Stewart at various times suggested that the air-currents in these regions may, owing to the lines of force of terrestrial magnetism, have electric currents circulating in them. The difficulty against this supposition always seemed to me to lie in the fact that the electromotive forces required to start a current were larger than those which could possibly exist in the atmosphere. But as there are very likely continuous electric disturbances going on, such as we observe in auroræ and thunderstorms, the regions within which these changes take place would act as conductors for any additional electromotive force, however small, so that any regular motion, such as tidal motions, could very well produce periodic effects affecting our magnetic needles.

'If these original discharges increase in importance, then, according to the results obtained in this paper, the currents due to the smaller periodic causes would increase also, and they may increase in a very rapid ratio. We know that the electric discharges in the upper regions of the atmosphere are considerably stronger at times of many sun-spots; and this may account for the fact that at those times the amplitude of the daily oscillation of the magnetic needle is considerably increased.'

There are six appendices attached to this report. The first and second of these are by Dr. Buys-Ballot, describing his method of separating between disturbed and undisturbed magnetic observations. The third is a list of stations at which magnetic observations have been made, compiled by Sir J. Henry Lefroy and Mr. Whipple. The fourth is a continuation

by Messrs. Stewart and Carpenter of their last report, in which Kew Declination Disturbances are classified according to the age of the moon, and in which likewise a comparison is made between declination disturbances and wind values with the object of finding whether there is any relation between these two phenomena. The fifth consists of some remarks by Sir J. Henry Lefroy on disturbances near the north magnetic pole; and the sixth, of some remarks by Mr. C. Chambers on the luni-solar variation of the vertical magnetic force at Bombay.

The Committee have drawn 26*l.* 2*s.*, and returned to the Association a balance of 13*l.* 18*s.* They would desire their re-appointment, and would request that the sum of 15*l.* should be placed at their disposal, to be spent as they think best on the subjects mentioned in this report.

APPENDIX I. *Letter from* DR. BUYS-BALLOT *to the Secretary.*

In the Second Report of the Committee on Comparing and Reducing Magnetic Observations it has been said, p. 51, 'Sabine's method has done good work in the past undoubtedly, but now the question has arisen, Has a better been proposed?'

You give some other propositions but do not mention mine, which I gave in 1862: 'Versl. der sectievergaderingen van het Prov. Utr. Genootschap.'

To this inquiry I was compelled by the very words of General Sabine, preface to the 'St. Helena Observations,' page xiv.: 'Until sufficient data should be obtained for the establishment of general laws regulating the times of occurrence and approximate magnitude of the disturbances in different parts of the globe the elimination of their influence by a process similar to that adopted at the colonial observatories, or by some process which should more effectually answer the purpose, must be a necessary preliminary to all precise investigations on other points.'

Now I ventured to imagine that the first question is: How to find the normal values of the declination and other elements, in order to know positively what are to be considered as disturbances? Acknowledging that a distinguished philosopher such as General Sabine had great experience and tact to distinguish the perturbed from the normal observations, it seemed to me that when the observations of several places are brought into comparison with one another, it were better to give a *rule* for separating the disturbances.

I proposed to take the general means of all observations without exception, and then to take the deviations, and to consider them all as disturbances. Further, I investigate in what manner the disturbances of different size, 0–1, 1–2, &c., minutes, occur at the various hours of the day, and fix the limit of ordinary and larger disturbances for each place, at that size, where the disturbances began to be distributed in another manner. This method I showed to be effectual in the above-named paper of 1862 in comparing the simultaneous disturbances at Toronto, the Cape, St. Helena, and Hobarton.

As now the international polar expedition took place, and it appeared necessary to calculate all these observations after the same method, I had care to reprint this paper in the 'Archives Neerlandaises,' 1884, and to submit it to the conference of the polar committee in Vienna, omitting only the discussion of the observations at Toronto, St. Helena, the Cape, and Hobarton, since it was only intended to show how to apply the

method, and since I showed it to be impossible to derive exact results from observations taken only hourly and not simultaneously, it being necessary to have as far as possible simultaneous observations by photography, or, of course, by assiduous observations, as now was the case.

As soon as the Pawlowsk observations were published I applied this method to them, though the disturbances were only taken from the supposed normals found by Professor Wild, a method which is also liable to some arbitrariness.

I arranged the disturbances thus found after their size, and found what is exhibited in Table II.

Dr. van der Stok, the Director of the Observatory of Batavia, who was then at Utrecht, spoke with me about this method, and he extended it somewhat more fully, submitting it also to the opinion of the members of the Polar Committee. He did more, and calculated the whole of the Batavia observations in this manner and sent me a proof-sheet of his sixth volume, where, pp. 188–190, Tables XXXIII.–XXXV., are to be found all disturbances distributed according to their size and sign for each hour when they occurred.

I have the honour to submit to you the result which I draw from the declination-disturbances alone, leaving it to him to attend to the ratio of the easterly and westerly, which I saw to be nearly unity, and limiting myself only to the distribution of the disturbances of each size over the various hours of the day. Table I. speaks for itself. When in this manner the observations of a greater number of places will be discussed, we shall be able to inquire in what manner the times of maximum and minimum differ for various places. The first thing to be done appears to agree concerning the method to be adopted—whether that of Chambers, Whipple, or Wild, as mentioned in your report, or that of Dr. van der Stok, combined with mine.

I take this opportunity for calling your attention to the observations of Utrecht (a place which is perhaps too near to Lisbon), but particularly to those of Batavia. If Utrecht be too near, I suppose, nevertheless, that Mr. Schuster will admit that the situation of Batavia and the excellence of the observations at that station require that it should be mentioned.

APPENDIX II. *Letter from* Dr. BUYS-BALLOT *to the Secretary.*

Utrecht: *April* 23, 1887.

Since you showed so much interest in determining the limits of the variations of declination which separate those which occur more frequently about noon or about midnight, I communicate to you the result of my research after the variations at Jan Mayen Island.

In the volume edited by Lieutenant Gratzl there occurs a table giving the frequency of the deviations from 0–5, 5–10, &c., for the different hours of the day.

I asked him if he could not supply, from the original paper, the frequency of the variations from 0–1, 1–2, &c., separately, and he has kindly answered my request.

The westerly and easterly deviations do not show a material difference; only for the westerly deviations the limit seems to be between 5 and 6, and for the easterly between 7 and 8.

Table I.—*Number of times the declination-deviations of different size occurred at the various hours of the day.*

Batavia Local Time						
Size	Total number for each six hours				Exact time of	
	2–7 Night	8–13 Morning	14–19 Day	20–1 Afternoon	Max.	Min.
0′–1′	631	376	470	835	24	12
1′–2′	1337	728	1159	1798	2	12
2′–3′	1142	732	990	1333	22	13
3′–4′	916	679	891	1072	23	13
4′–5′	652	594	724	706	16	12
5′–6′	525	550	557	468	9	24
6′–7′	372	459	469	292	14	1
7′–8′	278	415	375	156	14	22
8′–9′	188	362	267	111	12	1
9′–10′	159	326	188	63	12	23
10′–11′	143	264	135	41	8	23
11′–12′	111	230	105	24	13	21
12′–13′	72	215	85	21	12	23
13′–14′	56	179	73	20	12	24
14′–15′	42	107	46	6	12	22
15′–16′	36	84	25	8	11	21
16′–17′	26	98	26	9	12	20
17′–18′	20	61	23	3	12	24
18′–19′	16	62	15	6	13	24
19′–20′	14	61	13	6	11	22
20′–21′	6	15	5	5	11	24
21′–22′	13	35	4	4	11	22
22′–23′	9	29	7	1	13	22
23′–24′	8	21	13	0	10	23
24′–25′	6	25	5	1	12	22
25′+	18	91	13	10	12	22

Pawlowsk Time of Göttingen.				
Size	Number for each six hours of the negative (−) and positive (+) disturbances			
	4–9	10–15	16–22	22–3
0–2′	−836	−765	−888	−831
	+953	+854	+768	+829
2′–3′	−126	−182	− 73	− 76
	+ 80	+153	+131	+155
3′–4′	− 73	− 81	− 36	− 38
	+ 73	+ 77	+ 87	+ 98
4′–6′	− 68	− 80	− 25	− 28
	+ 24	+ 34	+111	+ 97
6′–8′	− 25	− 25	− 7	− 11
	+ 2	+ 20	+ 81	+ 41
8′–10′	− 14	− 8	− 4	− 6
	+ 4	+ 4	+ 36	+ 25
10′–12′	− 10	− 5	− 4	− 5
	+ 1	+ 0	+ 25	+ 16
12′–15′	− 3	− 6	− 2	− 7
	+ 1	+ 1	+ 21	+ 16
15′–20′	− 4	− 6	− 2	− 3
	+ 1	+ 4	+ 23	+ 5
20′+	− 3	− 4	− 3	− 2
	+ 1	+ 4	+ 18	+ 10

The whole number of disturbances, when they are less than 4′, is greater about noon; and, on the contrary, the disturbances which are larger than 5′ are more frequent about midnight.

The easterly and westerly disturbances are in the full table of Dr. van der Stok, vii. p. 188, nearly equal in number on the whole, though the ratio differs for the disturbances of larger and smaller size.

Therefore I think myself authorised to give for this place also the exact hour of the max. and min. for the sum of both (+ and −) disturbances, and find the hour of the max. for disturbances less than 4′ *before* noon, and the hour for disturbances greater than 4′ later in the afternoon, about at 20 o'clock.

Midnight = 0 hour; noon = 12 hours.

The negative disturbances (as given by Mr. Müller by the method of Prof. Wild) were found to be more numerous than the positive ones before 16 o'clock, especially the more so the larger they are, but on the contrary less frequent after that time of the day, 16–3.

It appears to be a consequence of some fault in the methods of Prof. Wild, and it would have been useless and not true to give them separately for each hour.

TABLE II.—*Number of Observations when the Simultaneous Deviations of the Magnetic Declination from the Mean at Utrecht (1882–83) differed from those at Pawlowsk as many minutes in + or — as are indicated in the Different Columns.*

Date	Total Number of Observations	0		1′		2′		3′		4′		5′		6′		7′		8′		9′		10′		11′		12′		
		+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	
Sept. 1	166	32	19	62	3	23	6	15	6																			
,, 15	281	67	49	28	55	9	28	4	22	2	15	1	1															
Oct. 1	282	14	46		66		54		85		16		1															
,, 15	280	58	50	31	48	17	30	16	18	4	5																	
Nov. 1	132	13	20	3	35		42		17		2																	
,, 15	275	24	23	15	11	13	12	18	8	20	2	20	21	21	16	12	1	19		6		7		2		4		
Dec. 1	279	6	8	7	28	2	104	1	88		26		7	2														
,, 15	283	35	4	122		94		16		6		2		1														
Jan. 2	282	15	56		101		92		11		2		2															
,, 15	283	45	19	39	18	12	11	4	2	41		73		15		1		3										
Feb. 1	284	8	16	8	40	3	42	2	68	4	40	3	16	10	3	12	1					2		2		1		{ 1 of 17, 1 of 18, 1 of 21
,, 15	282	87	65	99	3	4	20		1		1				1		1											
Mar. 1	168	32	21	28	22	21	19	5	12	2	1	1	1	2		1												
,, 15	284	77	48	95	22	32	3	7																				
Apr. 1	284	24	100	3	103	0	30	0	14	0	10																	
,, 15	266	15	116	9	86	4	24	0	12																			
May 1	167	26	47	6	24	8	27	2	27																			
,, 15	276	75	83	3	92	0	23																					
June 1	221	95	51	21	19	12	19	3	1																			
,, 15	284	57	89	15	79	0	29	0	15																			
July 1	273	23	54	22	69	8	30	7	15	5	10	8	6	3	3	2	2		5		1							
,, 15	283	25	20	23	6	47	1	79	3	51	2	15	1	4	0	3	0	3	0									
Aug. 1	282	38	41	24	52	7	34	9	19	10	16	3	9	1	4	0	10	0	2	0	1	0	1	0	3			
,, 15	281	65	79	10	92	9	20	1	2	1	0	2	0															

Nearly one third of the observations at Pawlowsk and Utrecht were so corresponding as to leave no difference of one minute. If you except the days of magnetic perturbation on which the needles both at Utrecht and Pawlowsk were restless, as November 15, 1882, January 15, 1883, August 1, 1883, the differences were only exceptionally greater than 3 minutes. And perhaps they would have been still more in accordance if at both places the true mean had been better defined. Utrecht has some observations missing, especially on November 1, 1882, on which day only 132 were registered, instead of $12 \times 24 = 288$.

Perhaps they would still better agree if the deviations had been taken from the true mean, and not from the, according to the method of Mr. Wild, somewhat arbitrary mean. It will be sufficient if I give here the sum of the positive and negative deviations for every six hours which show the greatest difference; so I find:—

	23–4	5–10	11–16	17–22
0–1	305	363	344	273
1–2	208	281	369	184
2–3	211	249	280	165
3–4	188	213	241	141
4–5	150	162	144	98
5–6	114	107	129	90
	1176	1375	1507	951

a greater frequency from 5–16 local time, and for each of the other differences without exception a greater frequency at the other hours. Therefore I mention only the sum of all the deviations greater than 6:—

	23–4	5–10	11–16	17–22
6+	829	630	497	1050

You will see that the range begins to be less pronounced for the deviations greater than four minutes, the two species of disturbances being already mixed.

The International Polar Commission as a whole has declined to enter into the proposal of Dr. Schmidt. I suppose, however, that every one of its members, as much as I, is very desirous that regular magnetic observations might be furnished to Dr. Schmidt in order that he may continue the work done by Professor Adams.—Yours faithfully, BUYS-BALLOT.

APPENDIX III. *Preliminary List of Magnetic Observatories.* *By* General Sir J. HENRY LEFROY *and* Mr. G. M. WHIPPLE.

The co-operative arrangements of 1839 were a great advance upon any previous international arrangement for scientific purposes. They wanted but little of completeness; unfortunately that little was of essential importance to the realisation of the object in view. There were no means provided for promptly interchanging observations, and no uniformity was established in the publication or in the scales adopted for measuring the variations of the different elements in terrestrial magnetism. The result has been an accumulation of volumes of observations, chiefly in quarto, at widely distributed stations, scarcely any two of which can be directly compared, the numerical values given requiring previous reduction to common units. It is practically much the same as if meteorologists all used arbitrary and different thermometers. But this chaotic condition of the elements of our magnetical knowledge cannot be much longer endured. The progress of the science is requiring more and more that all the material available for the elucidation of each class of phenomena—those which depend on the earth's diurnal rotation directly, that is to say, on the action of the sun, and those more remotely referable to it, or perhaps resulting from causes independent of it—be brought together. The following table has been compiled to facilitate such comparison by showing what records exist, and where they are to be found.

A List of Stations of more or less continuous Magnetical Observation arranged in order of Latitude.

Station	Lat.	Long.	From	To	Duration	Authority	How Published	Remarks
					Years			
Floeberg Beach	82° 27′ N	61° 22′ W	1875·9	1876·2	0·3	Nares	*Parl. Paper*, 1878.	
Discovery Bay	81 44 N	65 3 W	1875·8	1876·2	0·4	,,	,, ,,	
Lady Franklin B.	81 44 N	64 45 W	1881	1883	2	Greely	Official publication.	
Polhem	79 53 N	16 4 E	1872·8	1873·5	0·7	Wÿkander	,, ,,	
Cape Wilezek	79 50 N	58 56 E	1874·0	1874·2	0·2	Weyprecht	,, ,,	
Van Rensselaer Harb.	78 37 N	70 40 W	1854·0	1854·2	0·2	Kane	*Smithsonian*, vol. x.	
Cape Thordsen	78 28 N	15 42 E	1882	1883	1	Ekholm	Official publication.	
Fort Foulke	78 18 N	73 0 W	1860·9	1861·2	0·3	Hayes	*Smithsonian*, vol. xv.	
Lena Mouth	73 23 N	124 5 E	1882	1883	1	Jürgens		
Karmakule Bay	72 30 N	53 0 E	1882	1883	1	Andreje		
(Nova Zembla)	72 23 N	52 45 E	1882·7	1883·7	1	Snellen		
Port Kennedy	72 1 N	94 19 W	1858·8	1859·2	0·4	McClintock	*Phil. Trans.* 1863.	
Point Barrow	71 23 N	156 15 W	1852·8	1854·5	1·7	Moore-Maguire	*Phil. Trans.* 1857.	
Uglaamie	71 18 N	156 40 W	1882·9	1883·7	0·8	Ray	Official publication.	
Jan Mayen	71 0 N	8 28 W	1882·7	1883·6	0·9	Wohlgemuth	,, ,,	
Bossekop I.	69 58 N	—	—	—	—			
,, (Alten) II.	69 56 N	—	—	—				
Göthaven (Disco)	69 14 N	—	—	—				
Kultala	68 30 N	26 46 E	1884·0	1884·2	0·2	Lemstrom	Official publication.	
Södankyla	67 24 N	26 36 E	1882·6	1883·6	1·0	Biede	,, ,,	
Pitlekaj	67 0 N	173 45 W	1879·0	1879·3	0·3	Wÿkander	,, ,,	
Fort Confidence	66 54 N	118 49 W	1848	—	-	Richardson & Rae	,, ,,	
Kingua Fiord	66 36 N	67 20 W	1882·7	1883·7	1	Giese	,, ,,	
Göthaab (Greenland)	64 11 N	51 44 W	1882·7	1883·7	1	Paulsen	,, ,,	
Fort Rae	62 39 N	115 44 W	1882·7	1883·7	1	Dawson	,, ,,	
Fort Simpson	61 52 N	121 25 W	1844	—	—	Lefroy	,, ,,	
Helsingfors	60 10 N	24 57 E	1844·5	1848·1	3·6	Nervander	,, ,,	
St. Petersburg	59 56 N	30 16 E	1829	1834	5	Kupffer	,, ,,	
,,	—	—	1837	1862	25	—	,, ,,	Term days only.
,,	—	—	1868	1869	1	—	,, ,,	

,,	—	—	1869	1870	1	—	Unpublished.	
,,	—	—	1870	1871	1	Rykatchew	Official publication.	
,,	—	—	1872	1877	5	Wild	,, ,,	
Pawlowsk	59 41 N	30 29 E	1878	1885	7	,,	,, ,,	
,,	—	—	1886	1887	1	,,	In press.	
Fort Chipewyan	58 43 N	111 19 W	1843	1844	—	Lefroy	Official publication.	
Sitka	57 3 N	135 15 W	1832·9	1835·2	2·3	Wrangel	,, ,,	
,,	—	—	1842·0	1848	6	Hofman	,, ,,	
,,	—	—	1849	1853·6	4·6	Modendorf	,, ,,	
,,	—	—	1857	1861	4	Ossinine	,, ,,	
,,	—	—	1862	1864	2	Lyrianow	,, ,,	
,,	—	—	1865	1867	2	—	Not published.	
Catherinebourg	56 49 N	60 38 E	1837·0	1840·8	3·8	Remeke	Official publication.	
,,	—	—	1841·2	1848	7	Poskkow	,, ,,	
,,	—	—	1849	1864	15	Shortaew	,, ,,	
Kasan	55 47 N	49 8 E	1825	1826	1	Kupffer	,, ,,	Term days only.
,,	—	—	1829	1834	5	Simonow	,, ,,	,, ,,
Moscow	55 46 N	37 40 E	1882·7	1887	4	Weltzky	Unpublished.	
Makerstoun	55 35 N	2 31 E	1841	1855	14	Broun	Official publication.	
Stonyhurst	53 51 N	2 28 W	1863	—	—	Weld	,, ,,	
,,	—	—	—	—	—	Sidgreaves	,, ,,	
,,	—	—	—	1887	24	Perry	,, ,,	
Wilhelmshaven	53 32 N	8 9 E	1882	—	—	Borgen	,, ,,	
Manchester	53 26 N	2 13 W	1873	1887	14	Stewart	*Lit. Phil. Soc. Trans.*	
Dublin	53 21 N	6 16 W	1838	1850 (?)	12	Lloyd	Official publication.	
Barnaoul	53 20 N	83 47 E	1838	1864	26	Various	,, ,,	
,,	—	—	1865	1883	18	Sass	Unpublished.	
Irkutsk	52 17 N	104 16 E	(?)	(?)	—	Stelling	,,	
Helder	52 56 N	4 45 E	1852	1882	31	—	Official publication.	
Fort Carlton	52 52 N	106 32 W	1857	—	—	Blakiston	—	
Göttingen	51 32 N	9 57 E	1836	1841	5	Gauss	Official publication.	
,,	—	—	1882	1883	1	Schering	,, ,,	
Kew	51 28 N	0 19 W	1857	1864	8	Observatory	*Phil. Trans.*	
,,	51 28 N	0 19 W	1864	1874	10	,,	Not reduced.	
,,	51 28 N	0 19 W	1875	1887	13	,,	,, ,,	
Greenwich	51 28 N	0 0	1840	1887	48	,,	Official publication.	
Nertchinsk	51 19 N	119 37	1841·6	1845·7	4·1	Torbolow	,, ,,	
,,	—	—	1847·2	1849·0	1·8	,,	,, ,,	

A LIST OF STATIONS OF MORE OR LESS CONTINUOUS MAGNETICAL OBSERVATION ARRANGED IN ORDER OF LATITUDE *continued.*

Station	Lat.	Long.	From	To	Duration	Authority	How Published	Remarks
	° ′	° ′			Years			
Nertchinsk	—	—	1849	1852	3·0	Torbolow	Official publication.	
"	—	—	1853	1864	11·0	"	" "	
"	—	—	1865	1869	4·0	"	Unpublished.	
Brussels	50 51 N	4 22 E	1827	1887	61	Observatory	Official publication.	
Prague	50 5 N	14 25 E	1839	1887	49	"	" "	
Paris	48 53 N	2 20 E	1667	1887	221	"	" "	
Vienna	48 14 N	16 20 E	1852	1887	36	"	" "	
Munich	48 8 N	11 36 E	1840	1845	6	"	" "	
Buda-Pesth	47 30 N	19 2 E	1880*	1887	8	"	" "	* (? As to commencement prior to 1880.)
Nikolaieff	46 58 N	31 58 E	1829·8	1834·0	4·2	Kupffer	Official publication.	Term days only.
Lölling	46 55 N	14 0 E	1855	1865	11	Seeland	*Zeitschrift*, Band I.	
Milan	45 28 N	9 11 E	1836	1838	3	Kreil	Published.	
"	—	—	1870	1879	9	—	*Zeitschrift*, Band XV.	
Moncalieri	44 59 N	7 42 E	1870	1853	14	Observatory	Official publication.	
Eastport (Maine)	44 54 N	66 59 W	1860	1865	6	—	United States Coast Survey Reports.	
Pola	44 52 N	13 50 E	1885	1886	1	"	Official publication.	
Toronto	43 39 N	79 23 W	1841	1853	13	"	" "	
"	—	—	1853	1887	34	"	" "	
Portland (Maine)	43 38 N	70 16 W	1864·6	1866·2	1·6	"	United States Coast Survey Reports.	
Madison (Wisconsin)	43 5 N	89 24 W	1876	1881	6	"	Official publication.	
Nureuss	42 27 N	59 37 E	1874·9	1875·8	0·9	Dohrand	" "	
Rome	41 54 N	12 26 E	1860	1876	17	Observatory	" "	
Tiflis	41 43 N	44 48 E	1844·5	1846	1·5	Mielberg	" "	
"	—	—	1879	1882	3	"	" "	
"	—	—	1883	1887	5	"	Unpublished.	
New Haven (Connecticut)	41 19 N	72 56 W	1884	1885	2	—	United States Coast Survey Reports.	

Coimbra	40 12 N	8 23 W	1866	1879	14	Observatory	Official publication.	
Philadelphia	39 57 N	75 11 W	1840	1845	5	Bache	" "	
Pekin	39 57 N	116 28 E	1830·9	1832	1·1	Skatchkow	" "	Term days only.
"	—	—	1836·0	1837·0	1·0	"	" "	" "
"	—	—	1850·8	1855	4·2	—	" "	
"	—	—	1868·8	1870·7	1·9	Fritsche	" "	
"	—	—	1871	1881	10	"	" "	
Washington	38 53 N	77 0 W	1840	1887	47*	Observatory	" "	* At intervals.
Lisbon	38 43 N	9 8 W	1857	1887	30	"	" "	
Los Angeles (California)	34 3 N	118 15 W	1882	1885	4	"	United States Coast Survey Reports.	
Shanghai (Zi-Ka-Wei)	31 12 N	121 26 E	1874	1887	14	"	Official publication.	
Key West (Florida)	24 34 N	81 49 W	1860	1866	7	"	United States Coast Survey Reports.	
Havana	23 8 N	82 28 W	1863	1878	16	"	Official publication.	
Mexico	19 26 N	99 6 W	1879	1884	6	"	" "	
Colaba	18 54 N	72 50 E	1841	1887	46	"	" "	
Madras	13 4 N	80 14 E	1841	1860	20	"	" "	
Agustia	8 37 N	77 18 E	1855	1864	10	"	" "	
Trevandrum	8 31 N	76 59 E	1841	1869	29	"	" "	
Sarawak	1 34 N	110 29 E	1846·5	1846·7	0·2	Elliott	*Phil. Trans.* 1851.	
Singapore	1 19 N	103 57 E	1841	1845	5	Observatory	Official publication.	
Padang (Sumatra)	0 59 S	100 31 E	1847·8	1848·1	0·3	Elliott	*Phil. Trans.* 1851.	
Batavia	6 10 S	106 58 E	1846·9	1847·6	0·7	"	" "	
Batavia	6 11 S	106 49 E	1867	1887	21	Observatory	Official publication.	
Ascension, Isle of	7 55 S	14 26 W	1863·5	1866·3	2·8	Station	*Proc. Royal Society.*	
St. Helena	15 51 S	5 44 W	1841	1849	9	Observatory	Official publication.	
Mauritius	20 6 S	57 33 E	1876	1887	12	"	" "	
Sydney (N.S.W.)	33 52 S	151 11 E	1770	1871	105	"	" "	Declination at intervals.
Cape of Good Hope	33 56 S	18 28 E	1841	1846	5	"	" "	
Melbourne	37 50 S	144 58 E	1858	1887	30	"	" "	
Hobarton	42 52 S	147 21 E	1841	1848	8	—	—	
Kerguelen	49 25 S	69 53 E	1874·9	1875·2	0·3	Perry	*Proc. Roy. Soc.* vol. xxvi.	
St. Georgia	54 31 S	36 0 W	1882·7	1883·7	1	Schrader	Official publication.	
Cape Horn (Orange B.)	55 32 S	68 5 W	1882·7	1883·7	1	Cannellier	"	

APPENDIX IV. *Note by* Professor STEWART *and* W. L. CARPENTER, *Esq.*

We have now reduced all the available Kew declination disturbances after the manner described in the first report of this Committee, with the view of ascertaining whether there is any apparent connexion between disturbances and the moon's age. The following are the results obtained:—

Supposed connexion between disturbances and the Moon's age.
(0) = *new*, (4) = *full Moon.*

	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1858–61	72	76	75	81	101	105	90	75
1862–65	83	80	84	97	105	122	112	90
1866–69	88	91	78	64	52	69	74	75
1870–73	111	114	104	95	83	94	107	101
Mean of 16 years	88	90	85	84	85	97	96	85

From this table it will be seen that while the first two terms of the series exhibit predominant maxima a little after full moon, the last two exhibit predominant maxima a little after new moon. The mean of the whole indicates two maxima, one a little after new and another a little after full moon. This subject will engage our further attention.

We have likewise reduced these same disturbances after the manner described in the second report of this Committee, with the view of determining whether there is any apparent connexion between wind values and magnetic disturbances, and have obtained the following results:—

(α) Wind weather arranged so that *max.* values represent middle of series:

1858–61	−2,794	−1,958	−20	+2,402	+4,589	+6,272	+6,310	+5,148	+2,812	+336	−1,547	−2,999
1862–65	−3,748	−2,263	+437	+3,408	+5,205	+5,794	+6,037	+5,240	+2,939	+143	−1,718	−2,660
1866–69	−4,296	−3,621	−435	+3,325	+7,303	+8,248	+7,729	+5,699	+2,218	−508	−3,023	−4,060
1870–73	−2,384	−1,655	−101	+2,205	+5,935	+7,431	+7,022	+4,157	+1,501	−360	−1,667	−2,196
Total aggregate	−13,222	−9,497	−119	+11,340	+23,032	+27,745	+27,098	+20,244	+9,470	−389	−7,955	−11,915

(β) Dec. disturbance values so arranged that each entry of (β) is two days previous to each entry of (α):

1858–61	−1,129	−1,715	−1,571	−1,240	+453	+1,521	+1,945	+1,509	+1,287	+1,001	+590	−452
1862–65	−10	−183	+29	+550	+983	+1,519	+1,318	+402	−144	−291	−152	+141
1866–69	−1,657	−806	−302	+447	+885	+2,053	+1,907	+1,550	−470	−726	−1,152	−886
1870–73	−2,220	−652	+245	+1,110	+919	+693	+1,007	+466	+1,067	+588	+33	−186
Total aggregate	−5,016	−3,356	−1,599	+867	+3,240	+5,786	+6,177	+3,927	+1,740	+572	−681	−1,383

(γ) Wind weather arranged so that *min.* values represent middle of series:

1858–61	+3,453	+1,031	−2,206	−3,786	−4,703	−4,916	−4,837	−4,207	−2,915	−719	+638	+2,012
1862–65	+3,759	+1,681	−1,124	−3,434	−4,649	−5,045	−5,539	−5,023	−3,218	−680	+1,858	+3,486
1866–69	+4,672	+1,951	−822	−3,631	−5,471	−6,148	−5,959	−5,025	−3,682	−682	+2,337	+4,615
1870–73	+2,535	+1,114	−1,017	−3,393	−4,872	−5,312	−5,177	−4,740	−3,322	−1,680	+1,074	+3,196
Total aggregate	+14,419	+5,777	−5,169	−14,244	−19,695	−21,421	−21,512	−18,995	−13,137	−3,761	+5,907	+13,309

(δ) Dec. disturbance values so arranged that each entry of (δ) is two days previous to each entry of (γ):

1858–61	+2,023	+2,374	+1,021	−344	−672	−441	−513	−444	−696	−277	+251	+536
1862–65	+528	−254	−661	−258	−174	−494	−1,370	−999	−203	+187	+269	−95
1866–69	+1,355	+1,321	−355	−912	−1,151	−737	−471	−214	−249	−453	−5	−205
1870–73	+679	+177	−474	−1,022	−1,227	−487	−270	−367	−1,041	−980	−535	+116
Total aggregate	+4,585	+3,618	−469	−2,536	−3,224	−2,159	−2,624	−2,024	−2,189	−1,523	−20	+352

From these tables it would appear that high and low disturbance values correspond with and slightly precede high and low wind values.

APPENDIX V. *Communication from* Sir H. LEFROY *to the Secretary*

August 6, 1887.

The millimètre curve paper recently engraved by the Kew Committee, in accordance with the resolution of the International Polar Conference, will be of infinite service in enabling ready comparison to be made of mean results at different stations of observation. I have employed it in bringing together the mean solar-diurnal curves of declination, including all disturbances, for the winter months at stations on the American continent, namely—

				m.
Floeburg Beach	82° 27′	61° 20′ W	From M.P.	853
Discovery Harbour . . .	81 44	65 3 W	,,	795
Fort Conger (Greely) . . .	81 44	64 45 W	,,	790
Van Rensellaer Harbour . .	78 37	70 40 W	,,	650
Point Barrow	71 18	156 24 W	,,	1,130
Fort Confidence, Bear Lake . .	66 54	118 49 W	,,	508
Fort Rae, Slave Lake . . .	62 39	115 44 W	,,	642
Lake Athabasca	58 43	119 19 W	,,	765

To which I have added—

Polhem, Spitzbergen	79 53	16 4 E	,,	1,500
Island of Jan Mayen	70 59	8 28 W	,,	1,600
Kingua Fjord, Cumberland Sound.	66 36	67 20 W	,,	800

By M.P. is meant Ross's Magnetic Pole in lat. 70° 5′, long. 96° 43′.

It results that the first five curves on the list bear a strong resemblance to each other, especially in the exceptionally strong development of the mid-day curve, due to a preponderance of westerly disturbances when the sun is near the meridian; the next three, and the observations of the Swedish Arctic expedition to Spitzbergen in 1872–73, show an equally marked development of the night curve, due to a preponderance of easterly disturbances, having their maximum effect from 5 to 7 A.M. Captain Creak has remarked that at Discovery Bay 'the disturbing force during the day, that is, from 8 A.M. to 8 P.M., is considerably greater than that during the night between 8 P.M. and 8 A.M.' This is the reverse of what has been found in lower American latitudes; and it is especially remarkable that, if we complete the curve for Fort Confidence on Great Bear Lake by hand, for the hours of the night when observations were not taken, it is the case at that relatively southern station also, although the feature is conspicuously absent at Fort Rae on Great Slave Lake. It appears, therefore, that there is a region round the magnetic pole where westerly disturbances prevail, outside of which easterly disturbances prevail. This region extends towards the S.W. about 500 miles, but towards the N.E. as much as 850 miles. The Spitzbergen curve, notwithstanding the high northern latitude of the station, has the characteristics of more southerly stations on the American continent, as has also that of the Island of Jan Mayen. The curves at Great Slave Lake and Point Barrow closely resemble each other. Kingua Fjord on Cumberland Sound has the northern characteristics. I have dealt with the winter months only, because many of the stations were only occupied in the winter, and with the natural mean curves as affected by disturbance, for simplicity, because there is ample evidence that their exceptional character as compared with places distant from the magnetic pole is wholly due to what we call disturbance; and the few stations where the total disturbance has

been calculated, and analysed as disturbance east and disturbance west, sustain these conclusions.

If we could assume that the magnetic pole has travelled about 200 miles in a N.N.E. direction since 1831, and is now situated near the bottom of Prince Regent's Inlet, it would appear strikingly that the circle bounding the prevalence of westerly excess of disturbance is definite, and has a radius of about 700 miles round such a centre.

I am indebted to Brigadier-General Greely for the data in MS. for the curve for Fort Conger, which belongs to the year 1881–2, the fuller results for the year 1882–3 not having yet reached me. It appears, however, from their discussion by Mr. C. A. Schott ('Science,' March 4) that 'the most characteristic feature of the solar-diurnal curve (for the whole year) is the occurrence of the westerly extreme soon after local noon, with a deflection of 37′·9 reached earlier in summer and later in winter. The opposite extreme is reached an hour and a half after midnight, with a deflection of 27′·9, also found variable with the season.' 'The disturbing force deflecting the N. end of the magnet to the E. is most active two hours after midnight and least active during the hours noon to 5 P.M. On the other hand deflections to the west appear most frequent three hours after noon and least about the hours near midnight. Respecting intensity of action, easterly disturbances slightly exceed westerly ones.'

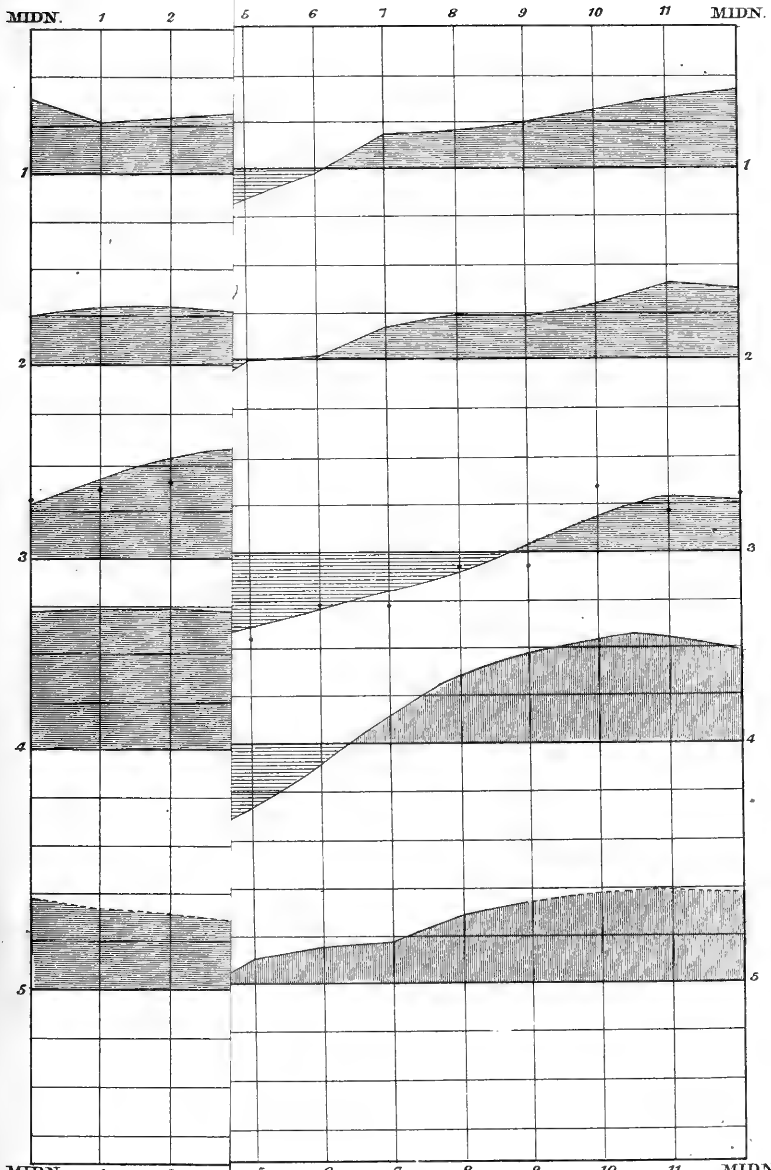
These conclusions are corroborated by the interpolated curve here laid down for the six winter months of 1881–2, although based upon only sixteen days of hourly observation, two or three in each month. The numerical values are taken from the official publications in each case, except Fort Conger and Fort Confidence, for which they are as follows:—

	Fort Conger	Fort Confidence		Fort Conger	Fort Confidence
	′	′		′	′
Midnight	12·2 E	19·6 E	Noon	25·3 W	27·9 W
1	14·9 E	17·2 E	1	28·1 W	24·0 W
2	15·8 E	16·3 E	2	23·1 W	16·7 W
3	27·1 E	14·3 E	3	24·2 W	8·2 W
4	29·3 E	11·2 E	4	17·8 W	1·6 W
5	15·7 E	8·2 E	5	13·8 W	5·8 E
6	6·8 E	4·7 E	6	10·4 W	7·6 E
7	23·3 E	0·8 E	7	11·2 W	9·4 E
8	12·4 E	13·6 W	8	2·9 W	14·8 E
9	2·4 W	31·9 W	9	3·1 W	17·3 E
10	8·2 W	35·4 W	10	14·0 E	19·8 E
11 A.M.	7·9 W	32·1 W	11 P.M.	7·8 E	20·0 E

APPENDIX VI. *Luni-solar Variation of the vertical Magnetic Force at Bombay. By* CHARLES CHAMBERS, *F.R.S., Director of the Colaba Observatory, Bombay.*

An account of the luni-solar variations of declination and horizontal force, derived from the registrations of the Colaba magnetographs for the single quarter, November 1875 to January 1876, appeared in the Report of the British Association for 1886, pages 84 to 97; and the registrations of the vertical force magnetograph for the same period have since been treated in the manner there described, and with the results shown in the following table:—

GROUP I. [...]PERIOD.

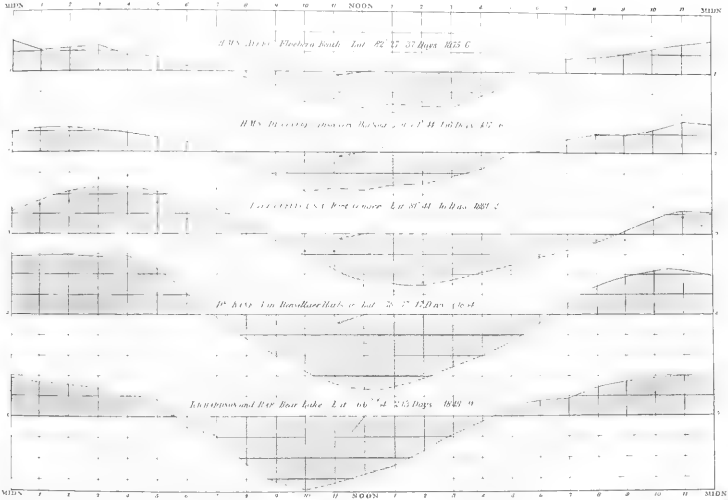


[...] Observations.

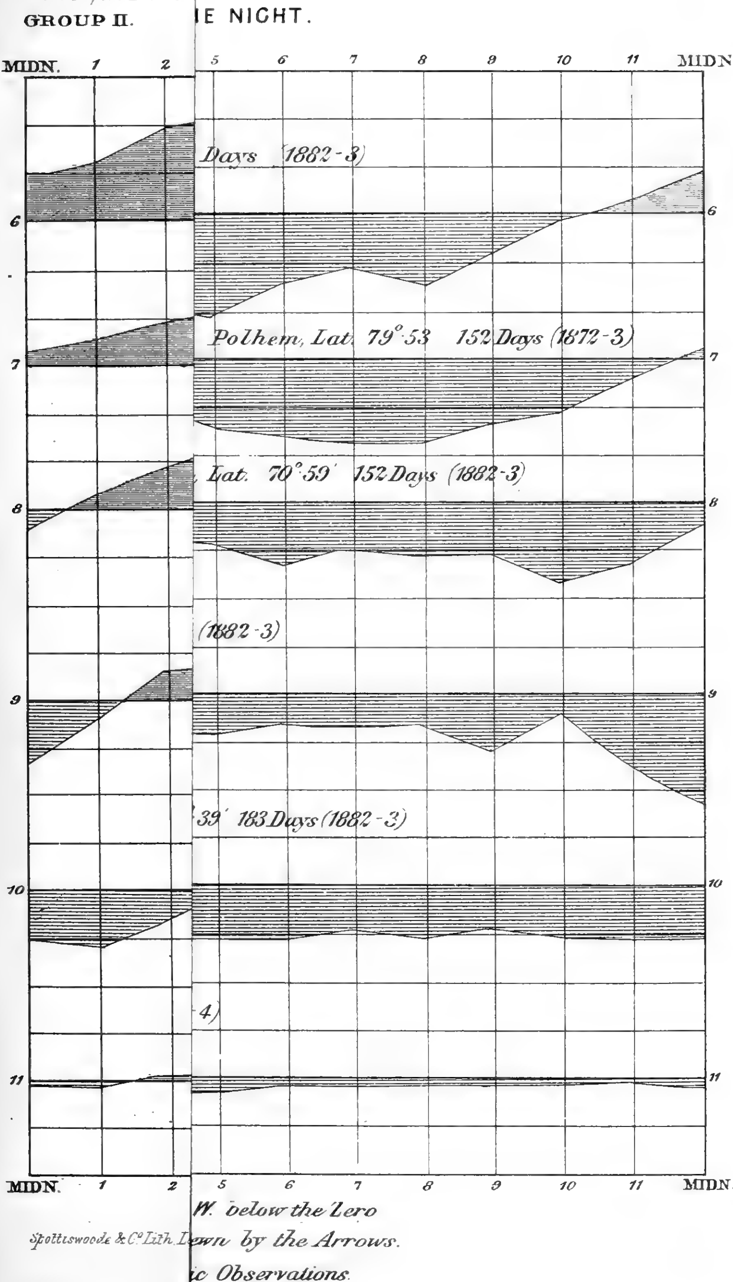
Spottiswoode & Co. Lith. London.

GROUP I

EXCESSIVE WESTERLY DISTURBANCE IN THE MID-DAY PERIOD



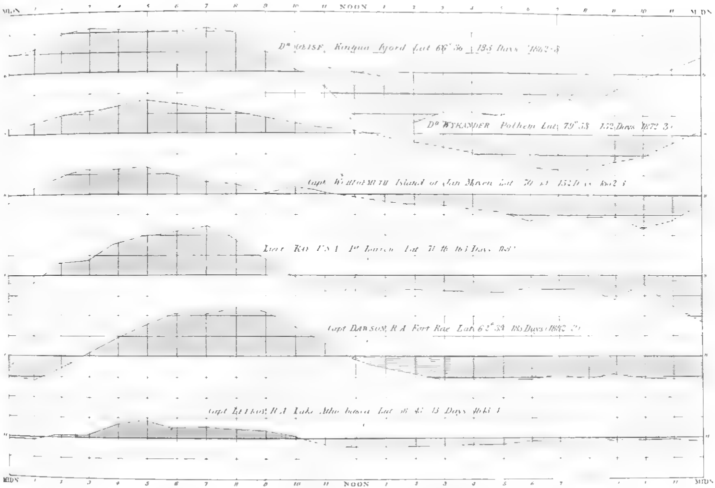
Illustrating the Report on the best Means of Comparing and Reducing Magnetic Observations



Spottiswoode & Co. Lith. L

GROUP II

EXCESSIVE EASTERLY DISTURBANCE IN THE HOURS OF THE NIGHT



Each Vertical Space is 1', Each Horizontal Space 10' E above the Zero W below the Line
The direction of the N end of the Magnet in Reference to the Meridian is shown by the Arrows
Illustrating the Report on the best Means of Comparing and Reducing Magnetic Observations

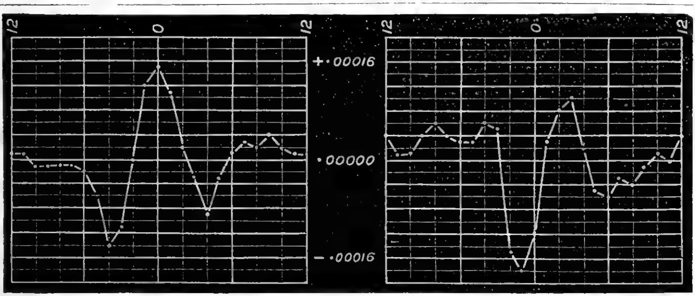
Solar hours	Midnight	1	2	3	4	5	6	7	8	9	10	11
$f_{c\cdot 2}(h)$	+01	+01	−01	−01	−01	−01	−02	−06	−14	−11	00	+12
$f_{s\cdot 2}(h)$	+04	+01	+01	+04	+06	+04	+03	+03	+06	+05	−15	−18
Solar hours	**Noon**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
$f_{c\cdot 2}(h)$	+15	+11	+02	−03	−09	−03	+01	+03	+02	+04	+02	+01
$f_{s\cdot 2}(h)$	−12	+03	+08	+10	+02	−05	−06	−03	−04	−01	+01	00

These variations are expressed in one hundred-thousandths of the m.-g.-s. unit of force.

Curves, representing the numbers of this table, and complementary to those of Plate I. of the British Association Report of 1886, appear below :

$f_{c\cdot 2}(h)$ VERTICAL FORCE. $f_{s\cdot 2}(h)$

Bombay Astronomical Hours.



The scale is in m.-g.-s. units of force.

they are, like their complements of declination and horizontal force, of definite character, showing relatively large movements in the day hours and quiescence at night, and they have a general resemblance to the declination curves; they also extend the evidence of the existence of a luni-solar variation to the third magnetic element at Bombay, and thus establish the fact in respect of the variations of magnetic force generally at Bombay.

On page 88 of the British Association Report for 1886 appears the following note: 'In the curves for declination, as sent by Mr. Chambers, the signs as given above are reversed.' The explanation is that the variations of the declination table are, as described, expressed in converted tabulation excesses, but that increasing tabulations (or ordinates of the registration curves) denote decreasing easterly declination, whilst increasing ordinates of the curves of Plate I. denote increasing easterly declination. The words 'Declination—East' at the side of the table refer to the absolute declination at Bombay.

Second Report of the Committee, consisting of Professors ARMSTRONG, LODGE, Sir WILLIAM THOMSON, Lord RAYLEIGH, FITZGERALD, J. J. THOMSON, SCHUSTER, POYNTING, CRUM BROWN, RAMSAY, FRANKLAND, TILDEN, HARTLEY, S. P. THOMPSON, McLEOD, ROBERTS-AUSTEN, RÜCKER, REINOLD, *and* CAREY FOSTER, Captain ABNEY, Drs. GLADSTONE, HOPKINSON, *and* FLEMING, *and* Messrs. CROOKES, SHELFORD BIDWELL, W. N. SHAW, J. LARMOR, J. T. BOTTOMLEY, H. B. DIXON, R. T. GLAZEBROOK, J. BROWN, E. J. LOVE, *and* JOHN M. THOMSON, *for the purpose of considering the subject of Electrolysis in its Physical and Chemical Bearings.* (*Edited by* OLIVER LODGE.)

WORK has been carried on during the past year by several members of the Committee; and nearly all the questions issued after the Aberdeen meeting by the Secretary have been in some shape or other attacked.

The first, 'On the Accuracy of Ohm's Law in Electrolytes,' by Professor Fitzgerald and Mr. Trouton, who reported last year and will make a further report to-day.

The second, 'On Conduction in Semi-Insulators,' by Professor J. J. Thomson and Mr. Newall. See the 'Proceedings of the Royal Society,' No. 256, 1887.

On the third question, the 'Mode of Conduction of Alloys,' Professor Roberts-Austen will inform us of his experiments to-day.

Mr. Shelford Bidwell has experimented on the subject of the fourth question, concerning the 'Transparency of Electrolytes.'

The sixth, seventh, and eighth, 'On the Velocity of Ions,' are being worked at by the Secretary.

Concerning the ninth we have heard from Mr. J. Brown, of Belfast, and on the tenth we have had a letter from Professor Willard Gibbs.

In order to enable the members of so large a committee to work with some knowledge of what each other is doing, and also to keep up a general intercommunication and interest in the subject, it has been thought desirable and proper to spend a certain portion of the sum granted to the Committee in printing and postage. Periodical circulars have been sent among the members and to a few outsiders likely to be interested, and these have been the means of drawing out one or two communications of very distinct interest and value.

It is felt that such informal reports of discussion and free circulation of provisional communications are sufficiently useful to justify the Committee in continuing the practice, which was begun as an experiment; and they accordingly are asking for reappointment, with another grant of 50*l.*, of which not more than 20*l.* is to be spent in printing and postage.

They should explain that of the grant made last year to the Committee 20*l.* has been purposely allowed to lapse, for it had been intended to try some chemical experiments on very pure substances, and these experiments have not yet been begun. The 30*l.* applied for has been spent—about 15*l.* in printing, 4*l.* in postage, and 11*l.* in experimental expenses contracted by the Secretary.

Your Committee feel that the expenditure of a small sum such as this has acted, and may be expected to act, as a trigger capable of liberating

in useful directions a considerable amount of energy which otherwise might have remained potential.

There are several moot points at present more or less under discussion within the Committee, and the editor is instructed to lay them before this meeting with the object of eliciting some opinions, suggestions, or information.

First may be instanced the obvious question whether electrolytic conduction and metallic conduction are sharply separated off from one another by a line of demarcation, so that no substance distinctly possessing one also possesses a trace of the other.

Certain contributions by von Helmholtz, among which we must reckon one on our list for to-day, lead one to believe that the conduction of ordinary electrolytes is *purely* electrolytic, and that no trace of current slips through them without carrying the atoms with it, *i.e.*, without effecting incipient decomposition.

A contribution expected from Professor Roberts-Austen may perhaps answer the opposite question, viz., whether any ordinary metallic alloy can conduct in the least electrolytically—*i.e.*, whether a well-marked metallic alloy or quasi-compound can be in the slightest degree electrolysed by an exceedingly intense electric current.

Supposing both these questions answered in the simplest manner, viz., in the negative, there must surely remain a group of bodies on the borderland between alloys proper and electrolytes proper, among which some shading off of properties, some gradual change from wholly metallic to wholly electrolytic conduction, is to be looked for. Until all such bodies as are tractable to experiment have been cautiously and strenuously examined, we are unable to say whether there is a hard and fast line between the two modes of conduction, or in what manner the gradation from one to the other occurs.

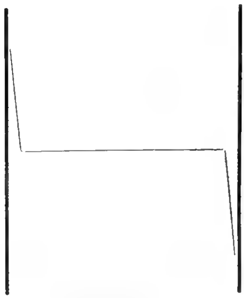
That is the first question. A second concerns the very vital point whether an electric current actually decomposes or tears asunder the molecules of a liquid through which it passes; or whether it finds a certain number of them already torn asunder or dissociated into their atoms by chemical, or at any rate non-electrical, means, and that these loose and wandering atoms thus fall an easy prey to the guiding tendency of the electric slope, and join unresistingly one or other of two processions towards either electrode, only at the last moment attempting a brief and unavailing struggle, when the electrode suddenly looms foreign and forbidding across a molecular distance of 10^{-8} centimetres.

One mode of regarding the facts is to say that across this molecular range of 10^{-8} the electrical forces *are* competent to tear atoms asunder. The E.M.F. of a volt or so can be shown by calculation to be able to do this, so that the difference between an electrolyte and a dielectric may be typified diagrammatically as on next page.

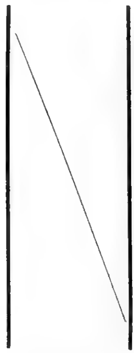
Professor Schuster has now discovered one way in which dielectrics shade off into electrolytes; for he finds that in the neighbourhood of an electric discharge rarefied gases are able to conduct as electrolytically as liquids themselves. This discovery that the atoms of gases possess atomic charge as well as those of liquids, if confirmed by further research, is one of considerable interest.

But why do we assert the horizontality of the line of slope in the fluid? Why do physicists feel constrained to assert that no internal

static electric stress is possible in the interior of a mass of fluid? The question is but the paraphrase of another. Why do we believe liquids to obey quite accurately Ohm's law for very minute forces? On this head we have direct experimental evidence by Professor Fitzgerald and Mr. Trouton, and less direct but equally conclusive evidence from von Helmholtz. Whether the evidence is perfect and thorough is doubtless a



Electrolyte.



Dielectric.

The two vertical lines are electrodes, the slant or broken line represents the kind of slope of potential in the two cases respectively.

debatable point, but this much is not debatable: it is out of the question to assert that liquids obey Ohm's law and at the same time to assert the existence of a finite electrostatic stress in the interior of a fluid. In other words, however chemists are able to explain the fact of unresisting atomic processions through the liquid—whether by actual procession of individuals or by continual directed interchange—they will be rigorously driven to some form of such doctrine as soon as they accept the evidence for the accuracy of Ohm's law in electrolytic conduction.

We all know that this doctrine of non-resistance is in some shape or another the old Williamson-Clausius hypothesis,[1] which was based on then newly known facts concerning dissociation.

It would appear, however, that some chemists demur to the existence of a constant average of dissociation among the molecules of a liquid; and it behoves us of Section A to receive their scruples with great respect, being, we may suppose, based upon intimate familiarity with all manner of circumstances and reactions of which we physicists are only superficially cognisant.

But there are ways of picturing all that is necessary to free atomic interchange without postulating actual and constant dissociation. A *potential* dissociation will be granted, sufficient for all purposes, provided chemists admit the probability of a frequent interchange of atoms among

[1] Since the Report was read, Professor Clausius has favoured the Committee with a note objecting to this designation as based on an erroneous view of scientific history. The Committee have not yet expressed their opinion on the point so raised, and meanwhile the joint names are used merely for convenience of quotation, without prejudice to an altered nomenclature hereafter.

the molecules of an electrolyte going on always before any E.M.F. has been applied.

Professor Fitzgerald now points out that without some further hypothesis it is not legitimate to assume that, because the least E.M.F. produces an electrolytic current, therefore there can be no force keeping the atoms in the molecules, and that consequently they must be in a continual state of interchange. If the work done during the combinations be equal to that required for separating the atoms in the molecules, then the least E.M.F. may produce its corresponding current. The Williamson-Clausius hypothesis is that these are both zero; but this is by no means the only possible hypothesis. In order that it shall be the only possible hypothesis it must be further assumed that the energy for decomposing a molecule cannot be transferred without considerable loss from a combining molecule. Any orderly connection amongst the molecules set up by the electric polarisation that would enable a transference of energy to take place from the combining to the decomposing molecules would explain the fact that the least E.M.F. produces its corresponding current; but if no such orderly relations amongst the molecules are possible then the Williamson-Clausius hypothesis seems to be almost certainly established.

This refers, of course, only to the reasons founded on electrolysis for the Williamson-Clausius hypothesis. The chemical reasons founded on the phenomena of double decomposition are independent evidence in its favour, except that there seems some difficulty in seeing how gases capable of double decomposition are not decomposed by the feeblest E.M.F.

Concerning the mode in which electrolytic conduction takes place we may congratulate ourselves on the presence here of Professor Quincke and Professor Wiedemann, and we hope to hear something from them. The experiments of Dr. Gladstone, and also some unpublished ones of Professor J. J. Thomson, communicated to the Committee in a letter, will probably be found to have a bearing on this point.

The question whether there is any radical distinction to be drawn between ordinary compounds and so-called molecular compounds appears to be an open one. Various physical facts lead one to suppose that whereas the ordinary forces of chemical affinity are strictly electrical there may be other non-electrical forces as well, and that such compounds as are held together by these latter forces are intractable to electrical influence. It is difficult for physicists to understand certain facts (cohesion, for instance, and capillarity) without the hypothesis of some non-electrical forces between atoms; but on such a subject as this chemists perhaps have in their hands evidence which, if at all decided and distinct, would be entitled to great weight.

The subject of the partition of the current among different electrolytes when mixed together, and the question of the part the solvent plays in the conduction, seem scarcely suitable for discussion at the present stage, because they only require a few rigorous experiments on lines already laid down to settle them. But the editor may just say that, whereas at a former meeting he thought he had obtained experimental evidence that the water conducted some fourth part of the current in certain solutions, he has since found that, using purer substances, and taking extreme care to avoid loss of weight by spray, which source of loss is very subtle, this evidence puts on another complexion; and at the present time he is disposed to coincide more cordially with the orthodox view that water conducts *almost* as little when forming part of a solution as when existing

alone. Further experimental evidence is still being obtained, however, and perhaps Mr. Shaw has something to communicate on this head.

Among several communications received by the Committee from non-British philosophers is an exceedingly suggestive one by Professor Willard Gibbs, which raises a very interesting point.

It is perfectly well known that in 1851 our present chairman, Sir William Thomson, reasoning from some experiments of Joule, taught us how to calculate the E.M.F. of a cell from thermo-chemical data—

$$E = \Sigma\,(J\,\varepsilon\,\theta)\,;$$

or

$$\frac{\Sigma\,\theta''}{46000}\text{ volts.}$$

Strictly speaking he hedged with regard to reversible heat effects in a way equivalent to the complete equation

$$E = \Sigma\,(J\,\varepsilon\,\theta) - \Sigma\,(J\,\Pi) \quad . \quad . \quad . \quad . \quad (1)$$

where Π_1 is the heat developed at junction 1 per unit quantity of electricity conveyed across it, Π_2 the same at the second junction, and so on.

But the value of Π, in any given case, is extremely difficult to measure, especially at metal-liquid and liquid-liquid junctions. Bouty has attempted it with but small success.

Fortunately Helmholtz has thought of applying the second law of thermodynamics to the subject, and shown that it was only necessary to know the rate at which the E.M.F. of a cell varied with temperature in order to know the sum of the Π. For, quite analogous to Professor James Thomson's freezing-point relation—

$$dp\,\delta v = J\frac{dT}{T}L,$$

is the following E.M.F. relation :—

$$dE\,\delta Q = J\frac{dT}{T}\delta H,$$

or

$$\Sigma\Pi = \frac{\delta H}{\delta Q} = \frac{T\,dE}{J\,dT} \quad . \quad . \quad . \quad . \quad (2)$$

Putting the two equations together we get

$$E = JT\varepsilon\int\frac{\theta\,dT}{T^2} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

which we may say is certainly true.

But now Professor Willard Gibbs suggests a novel mode of applying the second law or doctrine of entropy.

He takes into account the temperature of dissociation, or temperature at which the reaction could reversibly take place; and, calling this T_0, he writes the E.M.F. at any actual temperature T thus :—

$$E = J\theta\varepsilon\frac{T_0 - T}{T_0} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

This he gives as the complete expression; wherein, therefore, $J\theta\varepsilon$ is the chemical portion of the total E.M.F., and $J\theta\varepsilon\frac{T}{T_0}$ the thermal portion of the whole E.M.F., equal to $J\Sigma\Pi$. Equations (3) and (4) are plainly

identical if only heat of combination could be regarded as independent of temperature.

If this were a correct mode of regarding the matter, it would be of the highest interest to be able to calculate dissociation temperatures in this way. Unfortunately, several of the best judges in this country have expressed to the Committee their serious doubts as to the validity of thus stepping, unguided, outside the region of safe knowledge, across the great gap separating ordinary from dissociation temperatures. We wish Professor Willard Gibbs were here to support and strengthen his position.

These are the main problems at present under discussion among the members of the Committee, and with this summary of them and reference to such of to-day's papers as seem likely to contribute towards their solution, the report proper may be understood to close.

I think, however, I am only expressing the feeling of the Committee if I say that they view this joint sitting of Sections A and B with great interest, and with the anticipation and hope that it may be the precursor of many other such gatherings during the era of development in the borderland of chemistry and physics which in many directions they feel to be now imminent.

Experiments on the possible Electrolytic Decomposition of certain Alloys. By Professor W. C. ROBERTS-AUSTEN, *F.R.S.*

The original suggestions framed for the guidance of the Committee provided for an examination of the question whether molten alloys would conduct electrolytically, and during the year 1886 various experiments were made in the Mint laboratory, the results of which were in all cases negative, but were useful as indicating the method of working which appeared to afford the best prospect of success. The selection of a suitable alloy is by no means easy. It seemed well to begin by employing lead-gold and lead-silver alloys for the following reasons:—Matthiessen [1] has shown that these alloys, when considered from the point of view of their electrical resistance, belong to a class described by him as 'solidified solutions of one metal in the allotropic modification of another.'

Some work has already been done on the alloys considered as solutions of the precious metals in lead. I have already submitted to the British Association preliminary results on the diffusion of silver and of gold in molten lead,[2] and some unpublished experiments of my own have shown that certain silver-lead alloys when poured in spherical moulds, capable of holding about 2·6 kilogrammes of lead, set as a whole without exhibiting any tendency to the re-arrangement of the constituent metals known as 'liquation,' that is, the constituent metals do not readily fall out of solution. Such alloys are those which contain less than three per cent. of silver. The alloy containing 51·06 per cent. of silver, to which the formula Ag_2Pb may be assigned, also sets as a whole without re-arrangement of its constituents. Guthrie, in an admirable research, interrupted by his lamented death, has shown [3] that an 'Eutectic' alloy of silver and lead probably contains less than 1·5 per cent. of silver, that is, it is the alloy of the lead-silver series which has 'a minimum temperature of liquefaction, . . . a temperature lower than that given by any other proportion,' and he points out that such eutectic alloys are 'neither atomic nor molecular' in constitution.

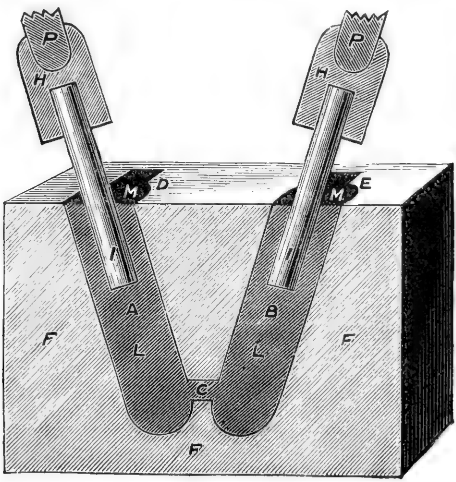
The curves representing the electrical resistance of *solid* lead-silver and lead-gold alloys are continuous, and do not reveal the existence of any special alloy differing widely in resistance and in physical properties from the rest of the series. In the case of the copper-tin series of alloys, investigated by Matthiessen [4] in 1860, by myself [5] in 1879, and by Dr. Lodge [6] in the same year, the alloys $SnCu_3$ and

[1] *Phil. Trans.* 1860, p. 161.
[2] Report for 1884, p. 675.
[3] 'On Eutexia,' *Phil. Mag.* 1884, vol i. p 462.
[4] *Phil. Trans.* 1860, p. 85.
[5] *Phil. Mag.* 1879, vol. ii. p. 57.
[6] *Ibid.* 1879, vol ii. p 554.

$Sn\,Cu_4$ stand quite apart from the rest of the copper-tin series both in colour, lustre, and electrical resistance.

It will be specially important to ascertain whether the passage of a strong current will enable the constituents of the copper-tin series of alloys to be separated, but unfortunately the alloys of these metals have high melting-points, and as the alloys have to be kept molten by the external application of heat during the passage of the current, the difficulties of manipulation are greatly increased. I considered, therefore, that it would be better to begin with the lead-silver and lead-gold series which have comparatively low melting points, and of which, as I have already stated, much is known concerning their behaviour as solutions. One additional advantage in the employment of these alloys is presented by the readiness with which variations in their composition may be determined. This is a point of some importance, for if, as Dr. Gladstone has already suggested, the results of passing the current through the molten alloys were only very slight changes in composition, the errors of analysis might overshadow the change. In the case, however, of the lead-gold and the lead-silver alloys, the method of assay by cupellation enables very minute changes in composition to be detected, and the amount of change can be determined with great readiness and accuracy.

Scale one-half.



P P, Cables from battery.
H H, Copper holders.
M M, Cavity for withdrawal of sample.
I I, Wrought iron rods.
F F F, Soft fire brick.
L L, Silver-lead or gold-lead alloy.

The preliminary experiments need not be described at length: it is only necessary to state that fire-brick U tubes, about five millimetres in section, were employed, and that in them the fluid alloy was kept molten by the external application of heat. The electrodes first used were stout iron-wire terminals of a forty-pint cell Grove battery; the passage of the current was maintained for thirty minutes and

portions of metal were tilted out from either end of the tube. These samples were then assayed and it was found that no variation whatever had been produced by the current. The passage of the current was not maintained during the time the samples were taken, and, as diffusion would probably rapidly restore the uniformity of the alloy, if the current did produce any change, care was taken in subsequent experiments to remedy this defect in the manipulation.

Dr. Lodge, in a letter to me dated April 5, 1886, asked whether it was possible to employ tubes one millimetre in section? I therefore broke off the bowls of two tobacco-pipes, leaving about ten millimetres of stem attached to each of the bowls which were then filled with the lead-silver alloy (containing two per cent. of silver) by placing them in a bath of the fused alloy and allowing the metal to enter the bowls through the stems. A current from the forty-cell battery was then passed for twenty minutes when both bowls were rapidly withdrawn. The contents proved on assay to be identical in composition. The ends of the stems while in the bath were about five millimetres apart.

The nature of the subsequent experiments is best shown by the sections of the fire-brick receptacles submitted to the Committee and by the diagram on previous page. The secondary batteries used for the electric lighting of the Mint were placed at my disposal by Mr. R. A. Hill, the superintendent of the Operative Department, to whose assistance I am much indebted. The weight of the alloy used in the experiments was about 500 grammes.

With the appliance arranged as shown in the diagram, the momentary application of twelve cells (supplied by the Electrical Storage Company) projected the metal (a five per cent. lead-silver alloy) from the fire-brick receptacle, while ten cells rapidly heated the iron terminals to redness and fused the lead 'lugs' of the cells. It was not found practicable to employ more than four cells for any experiment which lasted more than a few minutes, and in no case did the strength of the current exceed 300 ampères.

The following experiment with a gold-lead alloy containing about two per cent. of gold is given as showing the method of working:—Before melting the alloy two grammes yielded on assay 0·03981 grm. (or 1·99 per cent.) of gold; after the fusion had taken place the samples taken gave on assay the results shown in the following table. They were withdrawn from the cavities marked M,M, on the diagram at the periods indicated in the table.

Samples	Time from starting current	Weight in grammes of Gold obtained from two grammes of the Alloy	
		Positive Side	Negative Side
1	0′	(1) 0·04022 (2) 0·04007	(1) 0·03905 (2) 0·03855
2	10′	(1) 0·04029 highest (2) 0·04026	(1) 0·03954 (2) 0·03920 lowest
3	23′	(1) 0·03988 (2) 0·03973	(1) 0·03944 (2) 0·04010
4	40′	(1) 0·03980 (2) 0·03966	(1) 0·04009 (2) 0·04010
	Totals	0·23962	0·23847 [1]
5	45′	(1) 0·03917 (2) 0·04016	(1) 0·03926 (2) 0·04051

The current used was from three of the secondary cells connected in series.

[1] Total difference + 0·00115 grm

For the purpose of controlling the results, samples one and five were taken from the molten metal while no current was passing and were assayed with the rest. It will be seen from the above table that the difference varied from a minimum of one ten-thousandth as deduced from the total difference found on assaying samples two to four, to a maximum of five ten-thousandth presented by sample two. The alloys of lead with two per cent. of silver and with 51 per cent. of silver also gave negative results, and experiments as a whole, so far as they have yet been carried, tend to show that an alloy conducts metallically, and that its constituents cannot be separated by an intense electric current. The experiments, however, can only be considered to be preliminary. They must be repeated and extended, and alloys of which arsenic is a constituent must be tried, and further, it is specially important to examine the behaviour of such alloys as those of tin-copper and bismuth-gold, as certain members of both series show marked points on the curves representing the electrical resistance which would appear to indicate the existence of definite compounds.

On the Action of an Electric Current in hastening the Formation of Lagging Compounds. By Dr. J. H. GLADSTONE, *F.R.S.*

When two salts in solution, MR and M′R′, are mixed together they partially decompose one another, the proportions of the resulting four salts MR, MR′, M′R, M′R′, depending upon their relative masses and relative affinities. When one of these salts is insoluble, it separates as an amorphous or crystalline precipitate, and the redistribution goes on until the largest possible quantity of it is formed and precipitated. This reciprocal decomposition generally takes place very rapidly, but in some cases it proceeds slowly enough to be watched and measured. While investigating this subject a good many years ago, I made some experiments on the physical forces that accelerate or retard this action, and among them I tried the influence of a voltaic current passing through the mixture. I used a small Grove's battery with narrow platinum poles.

1. The first experiment was made with a mixture of tartaric acid and nitrate of potassium. The strength of the tartaric acid was 4·5 grammes, and of the nitrate of potassium 1·02 grammes to 1,000 grain measures (*i.e.* 64·8 cubic centimeters) of water; and the proportions used were three equivalents of the acid to one of the salt. In a comparative experiment four minutes elapsed before crystals began to appear. On making the current, the pole from which oxygen gas was being slowly evolved became immediately coated with potassic bitartrate, and crystals formed throughout the liquid between the poles.

2. A similar result was obtained with potassic oxalate and magnesic sulphate.

3. A mixture of single equivalents of magnesic sulphate and oxalate of ammonium was divided into two portions. Through the one a weak current was passed, and after a few minutes a cloudiness appeared, extending in lines from the one pole to the other, and not below the poles. As yet there was no cloudiness whatever in the comparative experiment.

4. A similar result was obtained with a mixture of calcic sulphate and strontium nitrate, but the lines of cloud extending from the oxygen towards the hydrogen pole were still more remarkable. The comparative mixture was quite clear.

5. A mixture of citrate of iron and meconic acid goes on increasing in redness for some time, but in this case all the compounds are soluble in water. No acceleration seemed to result from the passage of the galvanic current.

6. A mixture of citrate of iron and ferrocyanide of potassium shows a gradual formation of the blue ferrocyanide. This was hastened by the galvanic current; but there is this objection to the experiment, that the ferrocyanide itself was somewhat decomposed.

Last autumn a neighbour of mine, Mr. J. Enright, wrote to me to the following purpose:—'Thinking one day some few months ago over the decompositions and recompositions which we figure to ourselves as going on in an electrolytic salt, it occurred to me that we might get some confirmation, or the reverse, of them from

passing a current through a mixture of dilute sulphuric acid and a salt of strontium. It is well known that a precipitate does not come down for some time, and that such time is shortened by heating.' He then describes an experiment that is practically the same as my own, for which he used five Bunsen cells, and a similar experiment with a potassium salt and tartaric acid, and in both instances he obtained an acceleration, as I did. He adds, however, a somewhat different experiment. Cyanide of potassium was added to a solution of a nickel salt, and the first precipitate was redissolved in excess. Then hypochlorite of sodium was added. On boiling such a mixture, or allowing it to stand for some time, a black precipitate appears; but the moment the electrodes were inserted in a portion of the mixture, although cold, a black cloud was formed.

More recently Mr. Enright, at my suggestion, tried the effect of varying the strength of current. Using a mixture of strontium chloride and sulphuric acid, which would give a turbidity in about seven minutes without the current, he found that when exposed to the influence of seven cells the turbidity appeared in four minutes, of six cells about the same, of five or four cells in four minutes and a half, of three cells in six minutes, while two cells did not produce any acceleration that could be distinctly recognised.

On repeating my experiments lately the general results were confirmed, but I failed to secure the conditions under which the line of precipitate between the poles is produced.

These experiments seem in accordance with what might be expected if the electrolytic action takes place through the interchange of the radicals of the dissolved salts.

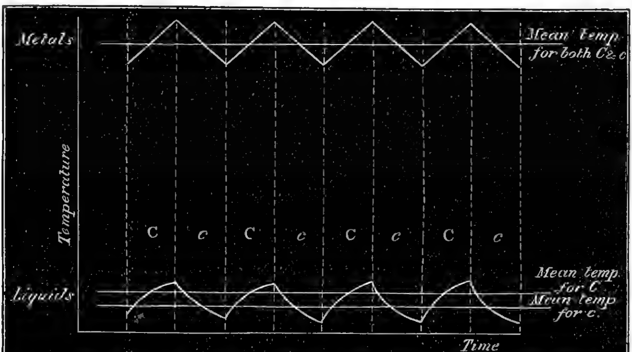
On Ohm's Law in Electrolytes.

By G. F. FITZGERALD, *F.R.S., and* FRED. TROUTON, *Trin. Coll. Dub.*

The result of our experiments up to this is to ascertain that 'h' in $[v=v_0(1-hc^2)]$ is certainly less than 5×10^{-6}.

This time last year it was hoped shortly to attain much greater accuracy than had then been reached, but it is clearer now than then what a difficulty the 'heating effect' is.

This inherent difficulty in studying Ohm's Law of liquid electrolytes, as compared with metallic conductors, may best be understood by considering the increased difficulty which would be introduced in the determination for metals if the wire were to be immersed in an electrically non-conducting liquid. When the



wire loses heat, chiefly by radiation, as when in air, its general temperature is so much above the temperature of surroundings that its rate of cooling may be considered constant for the small changes of temperature which can occur if the alternations from the larger to the smaller current be sufficiently frequent. The temperature thus rises at a constant rate while the larger current runs, and so falls

again during the time the smaller current is on, the average temperature in both cases being the same. The upper part in the diagram illustrates this.

However with the same frequency in changing currents the average temperature, while the larger current runs, may be made very different from the average temperature while the smaller current is on, by immersing the wire in liquid, for the general temperature of the wire can then be only slightly above the temperature of its surroundings, so that the rate of cooling can no longer be considered the same throughout. The lower part of the diagram is intended to roughly represent this. The temperature curve is concave to the lower side while the larger current runs, but is convex as the wire falls in temperature during the period of the smaller current. The 'temperature effect' if thus introduced would have to be met by increasing the speed of the contact breaker, or otherwise smaller currents should be used, which of course would diminish the refinement in the determination of 'h' correspondingly.

Now this is similar to the case of a liquid electrolyte, the smaller arm of the bridge rapidly losing heat by convection from its necessary proximity to the larger bodies of liquid at both ends. The actual rise in temperature in one experiment was ascertained, through the increased resistance, to be much less than ten degrees, while in some of the determinations made with metals the wire fused during the experiment so high a temperature was reached.

The greatest speed found necessary for the contact breaker in the determination with metal conductors, when 'h' was ascertained to be less than 10^{-12}, was about 100 per second. The fastest of the three forks we have successively employed is about 160 per second, but a much faster fork has been prepared, though as yet it has not been got to work satisfactorily.

The diameter of the smaller arm has been reduced considerably since last year. One hole of ·0027 c.m. was bored with a specially prepared needle in extremely thin mica. So that not much more can be done in this direction. The density of the greatest current which could be used through this without 'heating effect' was about ten ampères per square centimetre.

On the Resistance of Hydrated Salts. *By* Dr. E. Wiedemann.

With a view to the settlement of the question, whether or no the conductivity of a salt depends on the quantity of water to which it is attached in solution, the conductivity of solutions of copper chloride at different temperatures has been determined. At the lower temperatures the solution is blue, and at the higher

T	Copper Chloride		Sodium Chloride	
	L	D	L	D
5°	1·		1·	
10°	1·126		1·123	
		0·259		0·286
20°	1·385		1·409	
		0·259		
30°	1·644		—	0·593 = 2 × 0·296
		0·256		
40°	1·900		2·002	
		0·248		0·322
50°	2·148		2·324	
		0·257		0·336
60°	2·405		2·661	
		0·218		0·343
70°	2·623		3·004	
		0·187		0·350
80°	2·810		3·354	
		0·158		
90°	2·968			

green. We may explain this by assuming that at the lower temperature a highly hydrated salt is contained in the solution, and that this is changed into a lower hydrate as the temperature rises. In what follows we communicate the results obtained from a single solution only. This solution contained 15 parts $CuCl_2 + 2H_2O$ in 100 parts water. The conductivity of the solution at 5° is taken as unity. The conductivity of a 15 per cent. solution of sodium chloride was examined at the same time. In the appended table the column headed T contains the temperatures, L the conductivities, D the increase in conductivity for a rise of 10°.

The solution of sodium chloride shows, in agreement with results obtained by other investigators, a conductivity which increases with temperature more rapidly as the temperature rises; it agrees therefore in its behaviour with the majority of salts. For copper chloride, however, the rate of increase is nearly constant up to about 60°, and beyond this point rapidly diminishes. Solutions of other degrees of concentration than the above behave in a similar way; and this is true whether free hydrochloric acid be added to the solution or not.

The fact here ascertained, that the conductivity of salts varies with their degree of hydration, shows that it is absolutely necessary not merely to determine the constants under discussion for small temperature intervals and very dilute solutions, but also to vary the conditions of experiment in every way possible, since only then, and not always even then, can we determine whether such hydration has gone on or not.

The behaviour of copper chloride may be paralleled pretty closely by that of acid potassium sulphate, studied by Kohlrausch and Bouty.

I shall publish later the results obtained with other solutions of copper chloride, with those of cobalt chloride and other salts.

The experiments have been carried out with the assistance of J. Seyfferth.

On some Points in Electrolysis and Electro-convection.
By Professor G. Wiedemann.

I must congratulate the British Association on the reports of the Committee on Electrolysis, and specially that Professor Oliver Lodge has directed the course of its procedure, for it could not have been entrusted to abler hands.

Some time ago I read a very interesting report which Professor Armstrong communicated at the last meeting of the British Association, and the hypotheses he has advanced on the subject of electrolysis. There is a great deal that is hypothetical in these things. Allow me, therefore, to give expression to some aphoristical suggestions about some points more accessible to observation which I think ought first to be discussed.

I. The first question is, What is an electrolyte? What compounds are electrolytes? What are the ions of the electrolytes? Now, one generally says that electrolytes are salts, that they are binary compounds. But what is a binary compound? It is a compound decomposed by a current into two different compounds or elements; and when you say that electrolytes are salts you may as well say salts are electrolytes. Therefore it is very difficult to give a definition, and, even if we assume the general though not clearly defined idea of salts, we get into great difficulties. For instance, Professor Hittorf has said that electrolytes are compounds which by double affinity may exchange their elements with those of another recognised electrolyte. But that is not generally true. First, we have certain bodies which seem not to be decomposed by the current, though they exchange their elements with those of other compounds which are electrolytes. Take, for instance, anhydrous hydrochloric acid. It does not conduct. Nevertheless, as Dr. Gore has shown, if you put it upon carbonate of lime the carbonic acid is chased away and chloride of calcium is formed. And, to give another example, the chloride of propyle is a non-conductor; nevertheless, when you treat it with bromide or iodide of silver the chloride gets changed into bromide or iodide.

With just reason you may object that this is no proof, for perhaps the chloride

of propyle is only a very bad conductor; therefore the current does not pass in a sensible way, and we cannot observe the decomposition. In this respect we may refer to the researches of Mr. Bleekrode, in Holland, and Mr. Bartoli, in Italy.

But, on the other side, we find well-known electrolytes exchanging their ions with elements of other compounds which, without any doubt, are not their ions. So, for instance, chlor-acetic acid ($CH_2ClCOOH$), or the ethylic ether of this acid, and iodide of potassium exchange between each other the chlorine and iodine, though assuredly the ions of chlor-acetic acid are not Cl and CH_2COOH, but CH_2ClCOO and H.

Another difficulty is offered by the alloys. A former observation of Mr. Gérardin that amalgams of sodium grow brittle on one or the other electrode was refuted in my laboratory about eleven years ago by Dr. Obach.[1] His researches were made with the greatest care, and extended over different alloys, even those which contained definite equivalents of their elements, and which from their other properties seemed to be definite chemical compounds. But no decomposition was observed. Somewhat later Mr. Haga, in Holland, made analogous experiments with the same result. It would give me great satisfaction if Professor Austen should confirm these observations.

After these experiences we must confess that as yet we do not know the general definition of an electrolyte and of its ions.

II. There is another open question, whether water takes part in the electrolysis of a dissolved electrolyte. You have heard from Dr. Lodge that the answer to this question is generally negative. On the other hand, Professor F. Kohlrausch,[2] in his very remarkable paper on the conduction of some electrolytes in very diluted solutions, came to the opinion that in these solutions water is also decomposed. It would be very desirable that further researches should be made on this subject.

III. Let us neglect the surely very insignificant decomposition of water, and assume that it plays only a secondary part in the electrolysis of solutions. Then we may enter upon the consideration of their electrical resistance.

It is now generally admitted, as I detailed so long ago as the year 1858,[3] that the electrical resistance of a solution is determined by the mechanical resistance (friction) the bodies set free by the current encounter in the liquid, by which means the lost motion is transformed into a quantity of heat proportionate to the electrical resistance. In the same year I *compared* this friction with the viscosity of the liquid. I believe this has been often misunderstood, for I find it stated in some memoirs that I should have said the viscosity of a liquid *represents directly* its resistance. On the contrary, and specially in a paper of the year 1856, I have shown that the friction corresponding to viscosity is different from the friction in the electrolysis of solutions.

In the year 1870, in the second edition of my 'Treatise on Galvanism,' vol. i. p. 432, I have further detailed the three points separately to be considered in this electrolysis. viz., 1st, the friction of the ions in the liquid; 2nd, the friction of the dissolved electrolyte in the liquid; 3rd, the friction of the whole solution in the vessel, the electrical endosmose. I am happy to state that on these points I agree with my excellent friend, Professor Quincke, who independently and nearly contemporaneously evolved the same ideas.

We will omit the electrical endosmose, which can be eliminated, and deal only with the first two points.

The friction of the ions alone has been further treated by Professor F. Kohlrausch, and with the help of the admirable experiments of Professor Hittorf on the migration of ions, and his own most elaborate researches on conductivity, he has shown that, independently of the compound decomposed, each ion has its own constant velocity in the same solvent. The discrepancies which were observed in stronger solutions disappear, as Professor F. Kohlrausch has stated, in most

[1] Obach, *Pogg. Ann. Ergänzungsband,* vii. 1876, p. 280.
[2] F. Kohlrausch, *Wied. Ann.* xxvi. 1885, p. 211.
[3] G. W. *Pogg. Ann.* civ. 1858, p. 169.

dilute solutions, where the friction on the water is almost the only thing to be considered.

But with regard to very dilute solutions, I believe we encounter some great difficulties, at least for certain compounds.

1st. There may be double decomposition of the dissolved electrolyte with the impurities of the solvent. In very diluted aqueous solutions these impurities, even in the cleanest water, conduct better than the dissolved solid. It may be that this double decomposition may have no great influence on the results.

2nd. A greater influence can be exerted by dissociation of the salts. It is known that solutions of sulphate of copper, &c., are acid, that a solution of chloride of magnesia when boiled emits vapours of hydrochloric acid, that chloride and other salts of ammonia are dissociated in their aqueous solutions, &c. The increase of the dissolving water must increase these dissociations.

3rd. In many cases we are not sure if the dissolved electrolyte is to be regarded as free from water or as a hydrate (in alcoholic solutions as an alcoholate). By the researches of Graham, Rüdorff, and others, we know that such hydrates exist in the solutions. Now Professor F. Kohlrausch, in his already quoted memoir (p. 201), has found no influence of the formation of hydrates. On the contrary, Professor Eilhard Wiedemann, of Erlangen, has observed that there is a definite influence. You know that chloride of copper in very concentrated solutions is green, in more diluted blue. This change of colour is, without doubt, produced by the combination of the salt with the water. In the same manner diluted blue solutions grow green by a rise of temperature. Now the electrical conductivity of solutions of this salt at each rise of temperature of 5° C. augments nearly by the same amount up to 60° C.; but above 60° C. the change of conductivity for 5° falls off in a remarkable manner. The same is to be observed when the solution contains free hydrochloric acid. A solution of chloride of sodium—which salt forms no hydrates at not too low temperatures—shows no such irregularities. Its conductivity rises faster than the temperature up to higher temperatures. These experiments shall be further followed up. Without doubt the number of the salt molecules combined with hydratic water must increase with the dilution.

It seems to me at present impossible to avoid these disturbing circumstances, which nevertheless should be put into consideration. Therefore we should not content ourselves with the determination of the conductivities of very diluted solutions, by which certain complications are avoided, but new ones may be introduced. Only by the study of gradually changing concentrations of the solutions at different temperatures, and comparing their electrical behaviour with their other physical properties, may we get an insight into these different conditions.

The formation of hydrates of the salts and their dissociation must also be understood before we can enter with any hope of success into further discussion of the highly interesting and important question, principally treated by Dr. Svante Arrhenius, whether the eventual formation of complex molecules and their dissociation by further dilution may have an influence on the number of molecules decomposed by the current, and on the resistance of the solution.

For the same reason the question how much of the resistance may be due to the friction between the undecomposed salt and the dissolving medium, which have a certain difference of electrical potential between each other, and therefore are transported in opposite directions by the current, must be postponed for further researches.

IV. Another point which merits ample consideration and serious criticism is the supposed relation between molecular conductivity and chemical composition. The conductivities of dissolved salts give no such immediate relation; nor is any to be expected, since they are dependent upon the sum of the velocities of the two ions. The same may be said about the conductivities of worse conductors, the organic compounds, &c.

Great care should be taken in these researches to employ only chemically pure substances. After the interesting observations of Mr. Ramsay about the boiling points and vapour tensions of organic compounds, it seems not to be sufficient to content ourselves with getting them from even the best chemical works and testing them by their boiling points; especially as the conductivities of bad conductors

may be considerably changed by the addition of very small quantities of other substances.

By a long series of careful experiments Professor Ostwald has tried if there existed a relation between the mono, bi, and tri valency of the acids, and their molecular conductivities in very dilute solutions, which might be in inverse ratio to the valency $(100 : 50 : 33\frac{1}{3})$; but it seems not to follow from his researches; as, in solutions of different acids containing only one molecular weight in grammes in 1,000 litres of water, the numbers for the molecular conductivities vary for the monovalent acids between 112·5 (HBr) and 12·65 (isobutylic acid), for the bivalent between 113·4 (H_2SO_4) and 16·91 (succinic acid). The different changes of the molecular conductivities with increasing dilution (from 100 to 1,000 litres of water for H_2SO_4 from 102·7 to 113·4, for isobutyric acid from 4·41 to 12·65, &c.) cannot encourage us to a very far extended extrapolation which might conduct to the above law.

Therefore at present we must content ourselves with some minor regularities.

One of these has been observed in the laboratory of Professor Eilhard Wiedemann by Dr. Hartwig. According to his experiments the conductivities of the acids of the fatty series attain with rising concentration their maximum the earlier the more carbon they contain, and the later the more carbon the dissolving medium (water, methylic, ethylic, amylic alcohol), contains.

V. Also the attempt to measure the chemical strength of the acids by their molecular resistances seems to me to depend upon an erroneous conception. Already in my 'Galvanism' I have mentioned that the electrical resistance offers no measure for the so-called 'force of decomposition,' and therefore, also, not for the chemical affinity. May we assume the former view, that the ions of a compound are directly separated by the current, or, according to the now generally received theory of M. Clausius, that their motion is directed, or accelerated by it in a certain direction? After its interruption the electrolysed solution between the electrodes and far from them is quite unchanged. The work done by the current in separating the ions or changing their motion is totally regained by their recombination or their return to their former state.

The chemical affinity, or, more rightly, the heat of chemical combination, is measured by the electromotive force; and I believe that the law of Sir William Thomson, that the electromotive force of a cell is equivalent to the heat evolved in it, is true, if only we distinguish between the true primary chemical processes, which alone determine the electromotive force, and the secondary ones. For instance, in the magnesium cells we must calculate amongst the primary processes the formation of a highly negative suboxide of magnesium, in the cells with two liquids we must consider that their ions at their plane of separation appear and combine with each other in single atoms, while we measure directly their heat of combination when bound together into molecules, &c. In my 'Treatise on Electricity,' vol. ii. p. 892, I have, though but in a very few words, indicated some of these circumstances, which may explain the apparent objections to the law of Sir William Thomson. But these considerations would lead us too far from our proper subject.

VI. More intimate appear the relations between electrical resistance and the time for the formation of chemical compounds. In fact, this time depends (1st) on the affinity of the elements entering into combination or being exchanged between two compounds; and (2nd) on the mechanical resistance which they find, while approaching each other, and which mostly has been totally neglected in these questions. Both conditions must find their expression as well in the modern theory of atomistic and molecular motion as in the older one. The first of these conditions does not enter into the consideration of electrical resistance, the second does; so that even when in both cases the processes were quite the same, we could not expect a proportionality between the time of combination and electrical resistance. Nevertheless, the experiments of Professor Ostwald,[1] though treating very heterogeneous processes, indicate that between the time for the inversion of cane sugar, the catalysis of acetate of methyl by different acids, and their

[1] Ostwald, *Journ. für practische Chemie*, N. F. xxx. 1883, pp. 93–225.

electrical resistances there may be a certain relation; though the numbers, as may be expected, show considerable differences (if we put these constants for HCl equal to 100, they are for some other acids 65·1 and 73·4, 79·9 and 91, 74·6 and 104).

It seems to be very difficult, even if possible, to study both conditions which determine the velocity of the formation of compounds separately, and then compare only the resistance to their formation with the resistance opposed to their ions during the passage of the current.

So we see that a great deal of work has yet to be done in electrolysis, and I hope that the impulse given by the Committee of the British Association will mightily contribute to advance our knowledge in this most complicated and difficult problem.

Comparison between the Views of Dr. ARRHENIUS *and* Professor ARMSTRONG, *on Electrolysis. By* OLIVER LODGE, *F.R.S.*

It may be convenient to summarise the main views of Professor Armstrong concerning electrolytic conduction, as expressed in his Royal Society Memoir (*Proc.* Royal Society, No. 243, 1886). He discards the view of exact equivalence between the positive and negative atoms of a compound, considering that no ordinary molecule is really saturated, but that its electro-negative element has an unsatisfied or residual affinity, with which it is ready to cling on to fresh atoms or to other molecules. By means of these residual affinities of unsatisfied atoms he imagines molecular aggregates to be built up. And he considers a concentrated substance in the liquid state to be largely or wholly composed of these complex molecular aggregates, each in a nearly or quite saturated, and therefore inert, condition. The effect of dilution, however, is to break up these aggregates into simpler molecules, until, in an extremely dilute solution, the molecules may be as separated and as simple as they are in the gaseous state.

So far the views of Arrhenius [1] somewhat correspond. Without any doctrine of residual affinity as accounting for them Arrhenius also postulates the existence of molecular aggregates, which he imagines to be broken up by dilution; but he goes further, and imagines a certain number of the molecules themselves broken up by dilution into their constituent atoms, *i.e.*, he postulates real dissociation after the manner of Williamson and Clausius, a hypothesis for which Professor Armstrong sees no necessity, and to which he apparently perceives some chemical objection.

The dissociated molecules are called by Arrhenius the 'active part' of the liquid, and are believed to be the only ones which take part directly either in chemical action or in electrolytic conduction. These are the molecules which are constantly exchanging their atoms, either with each other or with foreign molecules, and so give rise to double-decomposition and ordinary chemical action. All other molecules, having their atoms firmly combined, are inert. Heating and dilution increases the active portion, *i.e.*, the proportion of dissociated molecules, and thus intensifies at the same time the chemical power and the electrolytic conductivity of the compound. To every state of temperature or admixture, a certain proportion exists between the active and inactive molecules of a given substance; and thus its 'activity' or 'avidity' in chemical reaction, as well as the current it can convey under the influence of a given E.M.F., *i.e.*, its conductivity, is regulated and determined. The velocity of chemical action between the mixed substances, *i.e.*, the rate at which their molecules interchange atoms, can thus be calculated in arbitrary time-units from a knowledge of the conductivity of the constituent substances; and the final state of equilibrium is obtained by putting this rate equal to zero.

The special point of Arrhenius's paper is therefore not any peculiar view which he holds regarding the nature of electrolysis, for his view is a perfectly orthodox

[1] 'Recherches sur la Conductibilité galvanique des Electrolytes (152 pages), par Svanté Arrhenius. Mém. présenté à l'Acad. des Sciences de Suède le 6 Juin, 1883.' Abstract and semi-translation appear in last year's B A. Report.

one, but it is the application which he makes of it in the consideration of all manner of chemical reactions; he attempts, in fact, an Electrolytic Theory of Chemistry.

Professor Armstrong, on the other hand, holds, provisionally at any rate, quite heterodox views as to the nature of electrolysis, which, so far as I understand them, appear to be these:—

Initially a salt-solution exhibits no trace of dissociation, there are no free or semi-free atoms to be acted on electrically, but so soon as an E.M.F. is applied to it a locomotion of the *molecules* past each other begins, as evidenced by the known occurrence of electric endosmose. By this process every salt molecule is brought within range of a water molecule as they slide past each other, and the residual affinity of some constituent of each of two molecules straining at each other under these conditions, superadded to the strain already set up by the applied E.M.F., is sufficient to effect disruption of the molecule, whose separated atoms then travel opposite ways to the electrodes carrying their charges with them, and conduction occurs in the manner ordinarily assumed. For instance, in a solution of HCl in H_2O, the O is straining at the Cl, and this force, as the molecules flow past each other, is sufficient to assist the applied E.M.F. to produce disruption and interchange, *i.e.*, to bring about the same result as the Williamson-Clausius dissociated condition ordinarily supposed to exist *before* the action of E.M.F.

If, however, the molecules in the liquid are all complex molecules, or aggregates of a large number of atoms, hanging together by the residual affinity of each, these residual affinities are in the complex so nearly satisfied that they have little or no further power to act on a water or other molecule; and they thus resist being broken up, and refuse to conduct a current. A liquid composed wholly of such complex aggregates is thus not an electrolyte; and Armstrong calls it a pseudo-dielectric.

A liquid which contains among a large proportion of such aggregates a few simple molecules here and there is an electrolyte but a very badly conducting one. Its conductivity increases as the aggregates get broken down, whether by heat or by dilution.

It will be observed that this hypothesis does not dispense with dissociation; it only denies dissociation previous to the application of E.M.F. So soon as E.M.F. is applied, mutual action between the molecules, assisting the strain caused by the E.M.F. itself, produces the very state of dissociation postulated by all physicists as necessary for actual electrolytic conduction.

Neither does the hypothesis dispense with a dissociating power of the solvent; it only limits its power to the breaking down of complex molecules, instead of allowing it to break up the simple molecules themselves. It is not supposed able to do this latter until aided by applied E.M.F.

To summarise.—The orthodox view supposes fully combined molecules, whether aggregates or not, to be undecomposable by any moderate E.M.F.; but it supposes a certain proportion of them split up or dissociated, either actually or potentially, by addition of a foreign body. Not necessarily a *solvent*: it pictures the dissociation of water by salt quite as easily as that of salt by water. Each atom while in the nascent or uncombined state has associated with it a definite electric charge, and these loose electrified atoms are thus immediately amenable to the smallest directive E.M.F.

Armstrong's view supposes complex molecules to be undecomposable by any moderate E.M.F., but it imagines a certain proportion of them split up or decomposed into simpler molecules by the action of a solvent. It supposes, further, a tendency or endeavour on the part of the water to split up these simple molecules still more into their constituent atoms; but it asserts that the water is unable to effect this until aided by an extra strain, in the shape of an externally applied E.M.F., and by the locomotive disturbance or endosmose thereby set up in the liquid.

A third view there is which must probably have been held more or less distinctly by several physicists, and which for several reasons usually commends itself to me, viz., that all *simple* molecules are strongly combined, and therefore intract-

able to feeble E.M.F.'s; and that most perfectly pure bodies, undisturbed by heat or by admixture with foreign matter, have their molecules in this condition. When, however, two or more substances (like salt and water for instance) are mixed together, their simple molecules combine into somewhat indefinite molecular aggregates or hydrates of complex structure, in which it may happen, either that some of the outlying atoms are not held with full vigour and so become partially free and able to interchange with other similarly placed atoms, or else that by the collision of the unwieldy aggregates with each other the atoms of one molecule are brought so close to the respectively opposite atoms of another molecule that a mutual interchange occurs.

For it is well known that it is quite unnecessary to postulate atoms as hovering around in an entirely free or disemmoleculed condition. All that is wanted to explain the facts of electrolysis is a certain number of atomic interchanges occurring at random; for the slightest E.M.F. will then suffice to exert a directive influence one way or the other on the atoms during their infinitesimal moment of freedom.

The operation is perhaps more simple to contemplate if the atoms are imagined to be actually, instead of only (so to speak) potentially, free, but the result is the same; and of course the conductivity will depend upon the number of such 'free' atoms existing in the solution, the *molecular* conductivity k/m representing the proportion of such free atoms to the whole. It is upon this very same proportion, according to Arrhenius, that the chemical activity of the substance depends.

Whatever be the most satisfactory form of hypothesis to hold at present, I am bound to say that the hypothesis of Dr. Armstrong does not commend itself to me. And that for several reasons.

I make no objection to his notion of residual affinity, nor to the formation of molecular aggregates by means of it. Those are points for the consideration of chemists. The objectionable, and I venture to think fatal, part of his hypothesis, is where he supposes dissociation to be produced by means of the applied E.M.F., instead of independently of it. Few things are more certain than this, that an electrolyte is incompetent to resist the smallest E.M.F. really applied to it (*i.e.*, not applied only to electrodes). If the molecules have to be torn asunder by any action depending on the magnitude of the applied E.M.F., it must be possible to choose an E.M.F. too weak to effect decomposition. A substance which needs an E.M.F. to tear its molecules asunder in the interior of its mass is *ipso facto* a dielectric—it may be a very weak one—but it is not an electrolyte. All that a slope of potential can possibly achieve in the interior of an electrolyte is to direct a procession of otherwise randomly moving atoms. This is, of course, the foundation of the theory of Williamson and Clausius; and all experimental knowledge acquired since the time it was first promulgated with regard to the obedience of electrolytes to Ohm's law, down to the researches of Professor Fitzgerald and Mr. Trouton, communicated in part to the last British Association and still going on, tends but to confirm and strengthen that position.

Of course, at surfaces of discontinuity (*i.e.*, at electrodes) electrolytes need a finite E.M.F. to liberate their ions, but the range over which the stress here concerned acts is of atomic dimensions, say 10^{-8} centimetre from each electrode. There is no such finite stress needed, or possible, in the interior of a homogeneous liquid.

A minor objection to Dr. Armstrong's hypothesis may be made at the point where he supposes *endosmose* to precede conduction, and to be a phenomenon independent of surface contact. It is not easy, again, to imagine why his molecules should be travelling past *each other* in the fluid, nor why, even if they did, this fact should assist their previously incompetent forces to disrupt each other.

Unless every molecule is supposed to be in a condition extremely like every other molecule, which is quite contrary to the usual doctrine of averages as applied to molecules, it is difficult to believe that a number of molecules are in such a state of strain as to be made to break up with mere gentle locomotion, and yet that none of them shall be able to break up without such assistance.

Comparison between the Views of Dr. Arrhenius *and* Professor Armstrong *on Electrolysis. Reply to* Professor Lodge's *Criticisms. By* Henry E. Armstrong, *F.R.S.*

Professor Lodge in his summary very clearly points out the difference in the views advocated by Arrhenius and myself, and emphasises the chief points which it is of importance to discuss. He unreservedly condemns my hypothesis, on the ground that any E.M.F., however small, is sufficient to produce sensible electrolysis; and he asserts this to be a proof of the correctness of the orthodox view that the E.M.F. has nothing to do but to give direction to the already separated atoms. I have before expressed my doubt of the force of this argument; but I may add that it appears to me hopeless to attempt the experimental disproof of such a statement, our ability to prepare pure substances being out of all proportion small as compared with our power of detecting electric currents: indeed, it would be presumption to attempt to contend with an engine of such surpassing delicacy as 'a galvanometer sensitive enough to show a current which could only decompose a milligram of water in a century.'

It is apparently desirable that I should more fully state, from a chemist's point of view, the chief reasons which cause me to hesitate in accepting the 'atomic dissociation hypothesis,' and which have led me to suggest an alternative 'molecular hypothesis,' viz., that in the case of 'composite electrolytes,' at all events, electrolysis is the outcome of the combined action of the E.M.F. and of some effect which the one set of molecules exerts upon the other set while both are under the influence of the E.M.F. I care little at present what the effect is, the important question to settle being whether electrolysis is primarily an affair of atoms or of molecules.

1. In explanation of the fact that neither hydrogen chloride (HCl) nor water (H_2O) is an electrolyte, although a solution of the one in the other conducts readily, it has been sometimes assumed that the dissociated atoms of H and Cl are shielded and prevented from recombining by the intervention of the neutral molecules of the solvent, opportunity being thus given for the E.M.F. to act and give direction to the atoms. But a *single* substance such as fused silver iodide, for example, conducts readily, and is electrolysed. How are we to explain this? I imagine that the orthodox view also in this case requires us to assume that there are, normally present in the iodide, dissociated iodide and silver atoms; just as it is assumed that there are atoms of H and Cl in hydrogen chloride, or of H and O in water. Why, then, does electrolysis take place in the one case, but not in the other? The conductivity of such a substance as silver iodide is far too considerable to be explained by the assumption that it contains impurity, which, judging from the behaviour of aqueous solutions, could not possibly be present in sufficient amount to account for the readiness with which the electrolysis takes place. Nor can we, with any degree of probability, suppose that either hydrogen chloride or water in the pure state consists wholly of Arrhenius's complex inactive molecules; that silver iodide is at all events rich in simple active molecules; and that such simple active molecules are produced from hydrogen chloride only on its dilution with water. Nor do I conceive that it helps us to assume that a compound of hydrogen chloride with water is formed; it does not appear to me to be probable that an aggregate of the form $(HCl)_y \cdot (OH_2)_x$ would be more susceptible of electrolysis than the component simple molecules, and that these would be more likely to suffer dissociation when associated than when free. Unwieldy aggregates, such as Professor Lodge refers to, break up, I imagine, if at all, not because some of the outlying atoms are not held with full vigour, nor because the atoms of the one constituent molecule are by collision of the aggregates brought close to those of the other, but because the atoms of the molecules which form the aggregate are brought into *intra-molecular* relationship; *i.e.*, the break up is not the result of the collision, but of the opportunity thus given for re-pairing to take place[1] and possibly new simple molecules, *not atoms*, always result.

[1] This view is in entire agreement with one I expressed in the communication referred to (page 353); indeed, it may be considered a paraphrase of it.—O. L.

2. Again, it appears to me that the atomic dissociation hypothesis requires that the majority of compounds, if not all, should *per se* conduct more or less well, especially if it be admitted that ionic velocities differ; as a matter of fact, however, only a very limited number can be regarded as electrolytes. Moreover, according to the orthodox view—particularly in the form in which it is stated by Arrhenius—the most active substances are those which contain the greatest number of active atoms, *i.e.*, those which are most easily dissociated. But, in point of fact, the substances which are most active—both chemically and electrically—are by no means those which we should regard as most likely to dissociate; thus, HCl, HBr and HI differ in stability to a very marked extent, yet their molecular conductivities in aqueous solution are almost identical. And a glance through the list of salts which are believed to be *per se* electrolytes is sufficient to show that these are not, as might fairly be expected, among the leaststable, but quite the contrary: silver chloride, bromide and iodide, for example—all compounds of considerable stability—being the best conductors known, I believe, among simple electrolytes.

3. Aqueous alcoholic solutions generally oppose a greater resistance than the corresponding aqueous solutions, and solutions in absolute alcohol oppose a practically infinite resistance; yet surely it might be expected that alcohol—indeed, any neutral solvent—would screen the dissociated atoms from each other and thus render electrolysis possible.

4. If, as Professor Lodge asserts, the orthodox view (or his version of it) pictures the dissociation of water by salt quite as easily as that of salt by water, why is conduction assumed by Kohlrausch and others to take place only through the agency of the atoms of the dissociated salt, and not at all through that of the water, except, perhaps, to judge from a recent admission made by Kohlrausch, in the case of *very dilute* solutions? Certainly, on the atomic dissociation hypothesis, both water and salt, I imagine, are to be regarded as dissociated; and, moreover, it would appear probable that as the dissociated constituent atoms of water would have less chance in a concentrated solution of coming together again, conduction would take place mainly through their agency; and that in a dilute solution, for a similar reason, conduction would be affected chiefly through the agency of the salt. This conclusion is manifestly opposite to that arrived at by Kohlrausch.

5. Arrhenius asserts that the conductivity of ammonia solutions is caused by a small quantity of NH_4OH, which is increased by dilution; and in reply to Professor Lodge's remark deprecating this statement (B.A. 'Report,' 1886, p. 363), he says: 'I may say in explanation that almost all chemists attribute the reaction of ammonia to a small portion of NH_4OH in it, &c.' I am one of those chemists who think that it is not necessary to make this assumption, believing that the chemical changes produced by ammonia solution are due to the combined or simultaneous action of ammonia and water, but I quite agree with Arrhenius that the effect of dilution is to increase the proportion of simple or active molecules, *i.e.*, to dissociate the molecular complexes into the constituent simple molecules of ammonia. The opinion is common among chemists that the nitrogen becomes separated from the hydrogen not by direct electrolysis, but by means of oxygen primarily produced by electrolysis—in other words, that water is the electrolyte.

6. The dissociation hypothesis has not only found favour with physicists, but also with chemists, as it long seemed to afford a simple explanation of the occurrence of chemical change; in fact, the popular view may be summed up in the simple statement that simplification as a rule precedes complication. As I have more than once insisted, however, recent observations on the influence of minute amounts of third substances oblige us to admit that we have yet much to learn regarding the manner in which apparently the simplest changes occur. In certain cases where we may almost assert that we know dissociated atoms to be present, combination or interchange does not ensue unless a minute amount of a third apparently neutral substance be present: indeed, the great problem in chemistry, which is but now being attacked, is whether it is possible for chemical change to occur between *any two* substances, be they simple atoms or more or less complex molecules. Even dissociation would seem not to be a simple function of tempera-

ture, as is well shown by the observations of Deville and Victor Meyer and Langer that the decomposition of carbon dioxide takes place in porcelain at a temperature several hundred degrees below that at which it occurs in platinum vessels. Moreover, there are not wanting chemists who assert that complication, not simplification, is the usual antecedent of chemical interchange.[1] No less an authority than Kekulé advocates this view, and I have recently had occasion to discuss its application in explanation of the laws of substitution in the case of carbon compounds. I do not mean for one moment to assert that anything which we know of the conditions on which chemical change depends negatives beyond question the dissociation hypothesis, but merely that it is possible, apparently, to explain the facts by means of a molecular hypothesis.

7. It appears to me that an almost conclusive argument in my favour may be based on the results of Lenz's determinations of electric conductivity and diffusivity embodied in the following table, where v is the volume percentage of alcohol, d the diffusivity, and L the conductivity; the values for an aqueous solution containing half a gram-formula-weight of potassium iodide being put = 100:—

	KI		$\frac{1}{2}$KI		$\frac{1}{4}$KI		$\frac{1}{8}$KI		$\frac{1}{16}$KI	
v	d	L	d	L	d	L	d	L	d	L
0	195	—	100	100	51	52	27	27	13	14
27·9	—	—	50	50	25	25	—	—	—	—
51·0	—	—	38	35	19	18	11	9	—	—
74·7	—	—	29	26	15	13	8	8	—	—

	$\frac{1}{2}$ Na I		$\frac{1}{2}$ K_2CrO_4		$\frac{1}{2}$ CdI_2		$\frac{1}{4}$ CdI_2	
v	d	L	d	L	d	L	d	L
0	82	80	—	104	84	30	44	18
27·9	38	40	64	63	40	14	19	7·5
51·0	—	—	—	—	37	9	17	4·5
74·7	27	23	—	—	39	6	17	3·5

It will be observed that the numbers run strictly parallel, except in the case of the cadmium salt; and here the exception proves the rule, as it is established, beyond doubt, by a variety of consistent observations that the cadmium salts are of exceptionally complicated molecular composition. I entirely fail to see how we are to explain liquid diffusion by means of the atomic dissociation hypothesis. But if we assume that the water molecules are in motion, and that having an attraction for the molecules of the dissolved body they necessarily tend to drag them forward, the phenomena are of the same order as those of conduction on my hypothesis. The diminution in conductivity and also in diffusivity as the amount of alcohol is increased is most striking. If the solvent be neutral the substitution of alcohol for water should have little influence; but if, as I suppose, the solvent be active, alcohol being far less active than water, the effect to be expected is precisely of the nature of that observed.

8. With regard to Professor Lodge's remark, 'It is not easy to imagine why his molecules should be travelling past each other in the fluid,' it is admitted by the orthodox that the E.M.F. gives direction to the atoms. Why, then, should it not also give direction to the moving molecules if these are still possessed of 'residual affinity'—*i.e.*, if some portion of the original charge of the atom be still unneutralised? He then adds, 'nor why, even if they did, this fact should assist their previously incompetent forces to disrupt each other.' Let me put a case. Imagine a

[1] This is in harmony with the 'third view' of electrolysis set forth in my paper (foot of p. 352).—O. L.

couple of individuals holding each other by the hand to waltz rapidly round a room, and suppose a second couple to do the same: if, as the couples passed each other, one of the individuals were to grab at one of the members of the other set, might not the members of the one or the other couple part company?

9. Ostwald's remarkable contributions to our knowledge of molecular conductivity appear to me to bear continuous testimony to the existence of such an influence of molecule upon molecule as that I have pictured. I have given numerous illustrations from his work in my Royal Society paper, but I may here call attention to his numbers for hydrocinnamic, cinnamic, and phenylpropiolic acids:—

	$v=32$	64	128	256	512	1024	2048	4096
Hydrocinnamic Acid, $C_6H_5.CH_2.CH_2.CO_2H$	2·25	3·14	4·40	6·08	8·42	11·55	15·71	20·92
Cinnamic Acid, $C_6H_5.CH.CH.CO_2H$ . .	—	—	—	7·55	10·37	14·18	19·18	25·28
Phenylpropiolic Acid, $C_6H_5.C.C.CO_2H$.	27·66	35·29	43·67	51·98	59·13	64·56	67·96	69·56

The numbers show that the 'activity' of the acid increases as hydrogen is withdrawn. On the orthodox view the ions are *H* and *the acid minus H*; but it is difficult to conceive that the affinity of the negative ion for H should diminish as that ion becomes deprived of hydrogen, and that that acid should be the strongest —*i.e.*, conduct best—because most dissociated, which it is to be imagined would be the least ready to part with hydrogen.

10. Arrhenius certainly bases his conclusion on the orthodox view of atomic dissociation, but in his calculations makes use of the conductivity values determined by himself or Kohlrausch; it seems to me, therefore, that his results are in the main independent of any theory of the nature of electrolysis. To use his words, 'L'activité electrolytique se confonde avec l'activité chimique;' or, to put it in another way, which much of our chemical experience appears to warrant, the formula by which Ohm's law is expressed

$$C=\frac{E}{R}$$

may also be used as representing the law of chemical change, C being the amount of change and E the intensity of the total chemical effect. An argument based upon electrolytic values may therefore be expected to be in agreement with chemical experience.

In conclusion, I would add that I urge these pleas on behalf of my hypothesis with the greatest diffidence, feeling that I am unfortunately unable to fully appreciate the force of the mathematical and physical arguments. I do think, however, that in framing our conceptions we may, perhaps, have been too much guided by statistical principles; it is quite open to question whether the *atoms* in molecules are in that state of unrest—are perpetually changing places in the manner in which our fancy has allowed us to picture them to be. We have yet almost everything to learn regarding inter-atomic structure, and everything regarding intra-atomic structure. It is impossible at present to quantify peculiarities and relationships which are patent to the chemist, but these must be taken into account; and for this reason it is all-important that chemists and physicists should co-operate.

The other contributions to the meeting were as follows:—

Professor von HELMHOLTZ (communicated by Dr. Silvanus P. Thompson), 'Further researches concerning the Electrolysis of Water.'—To be published by the Physical Society in the forthcoming volume of von Helmholtz's *Memoirs on Electrolysis.*

Professor H. A. ROWLAND, 'On chemical action in a magnetic field.' Paper not received.

Professor OLIVER J. LODGE, 'Experiments on the speed of ions.' Paper not written out in time for this year's report.

T. C. FITZPATRICK (communicated by Mr. W. N. Shaw), 'On the action of the solvent in electrolytic conduction.'—See the *Philosophical Magazine* for November 1887.

W. W. HALDANE GEE, H. HOLDEN, and C. H. LEES, 'On Electrolysis and Elec-

trolytic Polarisation.'—See the *Philosophical Magazine.* For abstract, see Trans. of Sections.

Professor M'LEOD, 'On the Electrolysis of a solution of Ammonic Sulphate.'—See the *Journal of the Chemical Society.*

Professor S. P. THOMPSON, 'On the Electro-deposition of Alloys,' and 'On the industrial deposition of platinum.'

Thirteenth Report of the Committee, consisting of Drs. E. HULL *and* H. W. CROSSKEY, Sir DOUGLAS GALTON, Professors J. PRESTWICH *and* G. A. LEBOUR, *and* Messrs. JAMES GLAISHER, E. B. MARTEN, G. H. MORTON, W. PENGELLY, JAMES PLANT, I. ROBERTS, T. S. STOOKE, G. J. SYMONS, W. TOPLEY, TYLDEN-WRIGHT, E. WETHERED, W. WHITAKER, *and* C. E. DE RANCE (*Secretary*), *appointed for the purpose of investigating the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations.* (*Drawn up by* C. E. DE RANCE, *Reporter.*)

YOUR Committee are of opinion that, looking at the large number of details of borings collected since their last report, and to the national importance of our underground-water stores, which have not failed in any public supply of importance throughout the kingdom, in spite of the exceptional drought, it is desirable that their labours be continued until there appears reasonable probability that the whole of the information on the subject has been procured, and that future observations will simply duplicate the knowledge already obtained.

Many of the problems to be solved have only as yet reached the preliminary stage of inquiry, while others require accurate observations by numerous observers, under varying conditions of character of soil, amounts of rainfall, and local conditions.

Cheltenham Water Supply is derived from springs issuing at the base of the sands of the Inferior Oolite, which yield a water described by the Rivers Pollution Commission as 'palatable, wholesome, and well suited for dietetic purposes, and is also much softer than most spring waters from the same strata.' Mr. McLandsborough, C.E., the engineer to the works, states the reservoir holds 200 days' supply, and is delivered on the constant system; he has gauged the springs on the hills above the reservoirs since 1864, and has never found them fail: during the severe drought of 1884 they yielded a volume equal to half the average daily supply of the period gauged. The minimum yield of the spring was in December of 1884, when the reservoirs were more than half full, and would have enabled the corporation to give a full supply if the drought had continued into the spring of 1885. In the Eleventh Report of your Committee, by a most unfortunate misprint, the reservoirs are described as 'dry' during the drought of 1884, instead of 'short,' as reported by a correspondent, in which statement he was obviously incorrect. Your Committee much regret that the condition of the Cheltenham Waterworks should have been misrepresented by them, as they were fully aware of the ample supply and pure quality given to the town by the corporation, the purity of which has been testified to by Drs. Allen Miller, Frankland, Way, and Tidy, and Professor Voelcker.

Analysis of Two Samples of Water from Cheltenham W. Corporation Works, August 13, 1887.

The results are stated in grains per Imperial Gallon of 70,000 grains, the Organic Carbon and Nitrogen being stated in parts per 100,000.

Description	Total Solid Matter	Ammonia	Nitrogen in Nitrates and Nitrites = Nitric acid	Oxygen required to oxidise the Organic Matter	Organic Carbon	Organic Nitrogen	Lime (CaO)	Magnesia (MgO)	Sulphuric Anhydride (SO_3)	Chlorine = Common salt	Hardness Befo Boiling	Hardness After Boiling	
	Grains	Grains	Grains	Grains	Part per 100,000		Grains	Grains	Grains	Grains	Degrees	Degrees	
Sample of water as supplied to Cheltenham from the Hewlett's Waterworks, belonging to the Corporation of Cheltenham	13·20	0·005	None	0·016	0·071	0·024	5·75	0·116	2·29	0·792 = 1·298	9·3	3·4	Silica 0·50 gr. Clear and bright neutral reaction
Sample of water as supplied to Cheltenham from the Dowdeswell Waterworks, belonging to the Corporation of Cheltenham. Taken from the pure water tank.	19·64	0·005	None	0·040	0·104	0·028	8·06	0·141	4·53	1·296 = 2·124	13·8	3·7	Silica 0·56 gr. Clear and bright neutral reaction

C. WEYMOTT TIDY, M.B., M.A.

Hertfordshire:—Record collected by Mr. G. J. Symons, *F.R.S.*
The Bury St. Edmund's Waterworks. Depth of Water in Well.
Depth of well, 91 feet 1½ inch.

1876		1876		1876	
July 1	12·6½	Sept. 6	10·6½	Nov. 11	10·2½
„ 3	12·5½	„ 7	10·7	„ 13	10·3
„ 4	12·5	„ 8	10·7	„ 14	10·3
„ 5	12·4½	„ 9	10·6½	„ 15	10·3½
„ 6	12·4	„ 11	10·7½	„ 16	10·4½
„ 7	12·3	„ 12	10·7	„ 17	10·4½
„ 8	12·2½	„ 13	10·7	„ 18	10·4½
„ 10	12·2	„ 14	10·7	„ 20	10·5
„ 11	12·1½	„ 15	10·7	„ 21	10·5
„ 12	12·1	„ 16	10·7	„ 22	10·5
„ 13	12·0½	„ 18	10·7½	„ 23	10·5
„ 14	11·11½	„ 19	10·7½	„ 24	10·5
„ 15	11·10½	„ 20	10·7½	„ 25	10·5
„ 17	11·10	„ 21	10·7½	„ 27	10·5½
„ 18	11·9	„ 22	10·7½	„ 28	10·6
„ 19	11·9	„ 23	10·7½	„ 29	10·6½
„ 20	11·8½	„ 25	10·7½	„ 30	10·7
„ 21	11·7½	„ 26	10 7½	Dec. 1	10·7½
„ 22	11·6½	„ 27	10·7	„ 2	10·8½
„ 24	11·6½	„ 28	10·7	„ 4	10·10½
„ 25	11·6	„ 29	10·7	„ 5	10·0½
„ 26	11·6	„ 30	10·7	„ 6	11·1½
„ 27	11·6	Oct. 2	10·7	„ 7	11·2½
„ 28	11·5½	„ 3	10·7	„ 8	11·3½
„ 29	11·5	„ 4	10·7	„ 9	11·4½
„ 31	11·4½	„ 5	10·7	„ 11	11·6½
Aug. 1	11·4	„ 6	10·7	„ 12	11·6½
„ 2	11·3½	„ 7	10·7	„ 13	11·8½
„ 3	11·3	„ 9	10·7	„ 14	11·11
„ 4	11·3	„ 10	10·7	„ 15	12·1
„ 5	12·2½	„ 11	10·7	„ 16	12·1½
„ 7	11·2	„ 12	10·7	„ 18	12·3½
„ 8	11·1½	„ 13	10·7	„ 19	12·4
„ 9	11·1	„ 14	10·7	„ 20	12·6
„ 10	11·1	„ 16	10·7	„ 21	12·7½
„ 11	11·0½	„ 17	10·7	„ 22	12·8½
„ 12	10·11½	„ 18	10·7	„ 23	12·9
„ 14	10·11½	„ 19	10·6½	„ 25	12·11½
„ 15	10·10½	„ 20	10·6½	„ 26	13·1½
„ 16	10·10	„ 21	10·6½	„ 27	13·2½
„ 17	10·9	„ 23	10·6½	„ 28	13·4½
„ 18	10·8½	„ 24	10·6½	„ 29	13·5½
„ 19	10·8	„ 25	10·6½	„ 30	13·6½
„ 21	10·8½	„ 26	10·6	1877. Jan. 1	13·9½
„ 22	10·8½	„ 27	10·6	„ 2	13·11½
„ 23	10·8	„ 28	10·5½	„ 3	14·1½
„ 24	10·7	„ 30	10·5½	„ 4	14·2½
„ 25	10·6½	„ 31	10·5	„ 5	14·3½
„ 26	10·6	Nov. 1	10·4½	„ 6	14·4½
„ 28	10·6	„ 2	10·4½	„ 8	14·6½
„ 29	10·6	„ 3	10·4	„ 9	14·8½
„ 30	10·6	„ 4	10·3½	„ 10	14·9½
„ 31	10·5½	„ 6	10·3½	„ 11	14·10½
Sept. 1	10·5½	„ 7	10·3½	„ 12	15·0
„ 2	10·5½	„ 8	10·3	„ 13	15·1
„ 4	10·5½	„ 9	10·3	„ 15	15·3½
„ 5	10·5½	„ 10	10·2½		

List of Questions circulated.

1. *Position* of well or shafts with which you are acquainted?

1*a*. State *date* at which the well or shaft was originally sunk. Has it been deepened since by sinking or boring? and when?

2. Approximate *height* of the surface of the ground above Ordnance datum (mean sea level)?

3. *Depth* from surface to bottom of shaft or well, with diameter. *Depth* from surface to bottom of bore-hole, with diameter?

3*a*. *Depth* from the surface to the horizontal drift-ways, if any? What is their length and number?

4. *Height* below the surface, at which water stands *before* and *after* pumping. Number of hours elapsing before ordinary level is restored after pumping?

4*a*. *Height* below the surface, at which the water stood when the well was first sunk, and height at which it stands now when not pumped?

5. *Quantity* capable of being pumped in gallons per day of 24 hours? Average quantity daily pumped?

6. Does the *water level* vary at different seasons of the year, and to what extent? Has it diminished during the last ten years?

7. Is the ordinary *water level* ever affected by local rains, and if so, in how short a time? And how does it stand in regard to the level of the water in the neighbouring streams, or sea?

8. *Analysis* of the water, if any. Does the water possess any marked *peculiarity*?

9. *Section* with nature of the rock passed through, including cover of Drift, if any, with *thickness*?

9*a*. In which of the above rocks were springs of water intercepted?

10. Does the cover of Drift over the rock contain *surface springs*?

11. If so, are these *land springs* kept entirely *out* of the well?

12. Are any large *faults* known to exist close to the well?

13. Were any *brine springs* passed through in making the well?

14. Are there any *salt springs* in the neighbourhood?

15. Have any wells or borings been discontinued in your neighbourhood in consequence of the water being more or less *brackish*? If so, please give section in reply to query No. **9.**

16. Kindly give any further information you can.

Collected by Mr. De Rance *from* Mr. D. Radford Sharpe,
Bocking, Braintree.

1. Belonging to Braintree Local Board of Health, situate in the parish of Braintree, Essex. 51° 52′ 15″ N. lat., 0° 33′ 15″ E. long. **1*a*.** 1854. No. **2.** 146 feet. **3.** Depth, 51′ 8″; diameter, 9′ 0″. Depth, 350′ 0″; diameter, 0′ 10″. **3*a*.** None. **4.** About 41 feet before, about 47′ 6″ after pumping, September 1882. At present, do not stop pumping long enough to tell. **4*a*.** 12 feet when first sunk. Cannot say where it would stand now. **5.** Cannot say. About 100,000 gallons average daily quantity pumped. **6.** Cannot say at present. Yes, about $5\frac{1}{2}$ feet. **7.** Not to the surveyor's knowledge. About 37 feet below surface of water in stream 22 yards off. **8.** One gallon contains the following number of grains and decimal parts of a grain (one gallon equals 70,000 grains):—

Analysis by Professor Attfield, *October* 2, 1880.

		Grains
Total solid matter, dried at 212° F.		77·00
Ammoniacal matter yielding 10 % of nitrogen (equal to ammonia, 0·07)		0·6
Albuminoid organic matter yielding 10 % of nitrogen		None
Nitrites		None
Nitrites containing 17 % of nitrogen		0·2
Chlorides containing 60 % of chlorine		55·0
Hardness (reckoned as chalk grains or degrees):—		
Removed on boiling the water	3·0	
Unaffected by ebullition	7·0	
Total hardness		10·0
Sodium, calcium, magnesium, traces of iron and alumina		Present
Silica, sulphates, and carbonates (magnesia, 2·3 grains), lead, or copper		None

Strata of trial bore only 145 feet above sea level.

		Ft.
	9. *Superficial Drift.*	
A	Sandy gravel	5
B	Drift clay or brick earth	9
	Tertiary.	
C	London clay	56
D	Here occurred a thin vein of sand, yielding water in small quantity	
E	London clay (continued) with sand and shells	40
F	Here occurred a stratum of hard cement stone, under which water was found, rising to within 5 ft. of surface, but not in any considerable quantity, about 10 or 12 inches thick	
G	London clay (continued) becoming gradually more sandy	30
	Lower London Tertiaries.	
H	Dark sand, with a few shells, yielding water in considerable quantity, which stood at 3 feet from surface	10
I	Mottled clays of smooth texture, veined like marble, and taking a polish from the knife	45
	(These clays became gradually more sandy, with specks of chalk, and at 194 feet changed suddenly to a coarse black sandy clay)	
K	Light-coloured sands, firm and hard, becoming darker and more friable	20
L	Another series of light-coloured sands, changing to coarse dark	13
	Secondary.	
M	Chalk at 228 feet from surface. In this water was found in abundance, rising to and standing at about 12 feet from the surface permanently.	

9*a*. In D, F, H, and M. **10.** Yes; one known of about 25 yards from well. **11.** Yes. **12.** Not known. **13.** No. **14.** None known. **15.** None known.

In the Ninth Report of this Committee, 1883, and also in the Twelfth Report, that for last year, is a weekly record of the level of the water in Messrs. Samuel Courtauld and Co.'s well at Bocking, Braintree, Essex, communicated by the courtesy of Mr. Radford Sharpe: this record is now continued. The well datum is 137·02 feet above the mean sea-level. The observations are taken every Monday morning at 6 A.M.; no water is taken on a Sunday. The rainfall observations given in the parallel columns in the first record are from a record kept at Fennes, Braintree, by Mr. S. Tabor, about a mile from the well.

For comparison with the table now given the following is the height of the water above datum, in inches, on the last Monday of each month:—

	1883	1884	1885	1886	1887		1883	1884	1885	1886	1887
January	16	16½	41	36	24	July	15	56	37	31½	21
February	10½	13½	42½	30	22½	August	11½	51½	35	26	—
March	19	14½	42	34	25½	September	11	45½	36	24	—
April	16	31½	44	33½	27	October	10	44	41	23	—
May	13½	49	42	31	25	November	16	40½	34	23	—
June	15	58	41	27½	22	December	9½	43	33	25½	—

The Essex earthquake happened on April 22, 1884; on April 21 the water in the well was 12 inches above datum; on the following Monday, the 28th, it was 31½ inches, steadily increasing until July 7 of the same year, when it stood at 58½ inches. Since then it has been steadily decreasing, and should the same rate continue until this month next year the remarkable lifting of the permanent water-level in Essex by the earthquake of April 1884 will have ceased to exist.

Weekly Readings of Height of Water in Messrs. S. Courtauld & Co.'s Well, Bocking, Essex.

Datum is 137·07 Feet above Sea-level.

Date 1886	Above Datum in Inches	Date 1886	Above Datum in Inches	Date 1887	Above Datum in Inches
July 26	31½	Dec. 6	24½	April 18	23
Aug. 3	27½	„ 13	25	„ 25	27
„ 9	26½	„ 21	20	May 2	27
„ 16	27	„ 28	25½	„ 9	23½
„ 23	26	1887. Jan. 3	25	„ 16	24½
„ 30	26	„ 10	26	„ 23	25
Sept. 6	26	„ 17	23	„ 31	25
„ 13	24	„ 24	23½	June 6	24
„ 20	25	„ 31	24	„ 13	23½
„ 27	24	Feb 7	21½	„ 22	22
Oct. 4	24	„ 14	24	„ 27	22
„ 11	25	„ 21	25	July 4	22
„ 18	27	„ 28	22½	„ 11	22
„ 25	23	Mar. 7	24	„ 18	19
Nov. 1	23	„ 14	26	„ 25	21
„ 8	24	„ 21	26	Aug. 2	18½
„ 15	20½	„ 28	25½	„ 8	18
„ 22	20½	April 4	26	„ 15	18
„ 29	23	„ 12	26	„ 22	18

Warwickshire.

The Birmingham Corporation Waterworks now daily obtain 8 million gallons of water from three deep wells in the suburbs, two on the north and one on the south.

Aston Well, 2 miles north of Birmingham.

	Feet
Gravel	10
Bunter sandstone	232
Red marl	36
Sandstone	10
Red marl	15
Very hard sandstone	53
Marl	45
	401

The first 120 feet is a well, the remainder is bored.

The Perry Well is 170 feet in depth.

The Short Heath Well is 130 feet, with a boring to 400 feet.

At Messrs. Heaton's Mint the well is 300 feet in depth.

Nearly the whole of this supply is derived from the Pebble Beds, which are cut off to the east of a fault ranging N.E. and S.W. by Rubery to Erdington; eastward a considerable area of Keuper marls extend from Birmingham to Shustoke, and from Tamworth to Warwick and Redditch, and form an area of surface water supply from drift superficial deposits. Numerous attempts to obtain a good supply of water from the sandstones beneath have been made, but so far without success.

The small Heath boring, for the Birmingham Corporation, made in 1876, in search of water for baths, was discontinued, after proving 440 feet of Keuper marls with gypsum.

King's Heath Brewery, 3 miles south of Birmingham, and about $1\frac{1}{2}$ mile from the Edgbaston Fault, which is probably a downthrow east of 240 feet. Boring made by Messrs. Le Grand and Sutcliffe for Messrs. Bates.

	Feet	
Old well	32	Drift.
Red sand	4	
Red mud and pebble	8	
Rough ballast	12	
Red marl	158	Keuper marls.
Gypsum and Keuper marls	131	
Marl, gypsum	309	
Marl and shale	$3\frac{1}{2}$	
Red stone and shale	$9\frac{1}{2}$	Keuper sandstone (?).
	667	

The following is the section of the Rugby Corporation boring:—

From surface Feet		Thickness Feet
400	Lias	400
470	Rhætic beds	70
1,140	Keuper marls	670
—	Keuper sandstone	(+)

The water at once rose in the borehole, but was so impregnated with salt and gypsum as to be useless.

Leicestershire.

Hinckley Boring, 1 mile W.N.W. of Hinckley.

Surface level 317 feet above Ordnance datum; water level 237 feet. Commenced November 1877.

From surface Ft.	In.		Thickness Ft.	In.
1	0	Soil	1	0
31	0	Gravel and sand	31	0
88	0	Boulder clay	57	0
100	0	Upper Keuper sandstone	12	0
496	0	Keuper marls	396	0
700	0	Grey sandstone, marls, sands, and gypsum	204	0
749	0	Grey sandstone	49	0
761	0	Hard brown sandstone	12	0
772	0	Soft white sandstone	11	0
776	0	Hard grey sandstone	4	0
782	0	Soft white sandstone	6	0
783	0	Hard marl	1	0
799	0	Soft fine white sandstone	16	0
805	0	Hard gritty sandstone	0	6

A 13-inch tube is carried down to the bottom of the boulder clay, a 10-inch tube to a depth of 161 feet, an 8-inch tube to 420 feet, a 7-inch tube, with an inside diameter of $6\frac{3}{4}$ inches, to 473 feet, after which the borehole is not tubed, but was carried to 754 feet by the advice of Mr. Plant, F.G.S. In 1883 the board consulted Mr. Stooke, C.E., of Shrewsbury, who advised a further boring, which was carried to a depth of 805 feet, with a diameter of 3 inches. An attempt to plug out the top saline waters was made without success.

The water from the borehole contains 530 grains of solids and 39 grains of chlorine, and the yield is 400,000 gallons per day.

Staffordshire.

Mr. H. J. Marten, M.Inst.C.E., gives the following details of the borehole sunk under his superintendence at Cosford, 9 miles from Wolverhampton, for the corporation waterworks of that town:—

	Ft.	In.	Ft.	In.
Upper mottled sandstone			461	6
Pebble beds:—				
Upper pebble beds	165	6		
Argillaceous marl	85	0		
Lower pebble beds	128	0		
			378	6
Lower mottled sandstone (+)			78	9
			918	9

He states the water rises to 9 feet above the level of the ground, or about 201 feet above Ordnance datum, the natural discharge being at the rate of 480,000 gallons a day. Opening a sluice 14 feet below this, the natural discharge is 830,000 gallons a day. On pumping down the water level 27 feet below the 'summit level,' the yield is increased to 1,320,000 gallons a day, and at 31 feet to 1,420,000 gallons per day of 12 hours.

There was a slight briny ooze, estimated at about 300 gallons a day, from the argillaceous marl bed.

Mr. H. J. Marten also describes the Tamworth Waterworks well, sunk at Hopwas, 2 miles west of that town:—

	Ft.	In.
Drift	16	6
Red marl, with rock bands	15	11
Hard conglomerate	5	7
Argillaceous marl	39	11
Fissured sandstone	13	9
Argillaceous marl	5	0
Light fissured sandstone	30	4
Red marl, with layers of greyish blue stone and balls of marl, with dark spot in centre, called 'fish-eyed' marl	41	0
	168	0

No water was met with in the Hopwas well until the 'fish-eyed' marl was penetrated at 168 feet, when a large spring with an initial flow of 1,500,000 gallons a day was met with, and rose 39 feet in the well, or to 129 feet below the surface, which is about 306 feet above Ordnance, the artesian level being 177 feet. A slight ooze took place in the fissured sandstone, and a remarkable current of air was met with in it, fluctuating with the barometrical changes, with a rising glass there being a decided indraught from the well into the fissure, and the contrary taking place with a falling barometer; a very active outflow during the whole of one day was succeeded at night by one of the most violent storms of the period (1879). The fissure is evidently connected by passages with the surface of the ground.

A Report to Tamworth Rural Sanitary Authority on its Water Supply, by Mr. HENRY J. MARTIN, *M.Inst.C.E., gives the following Particulars of Samples of Water Analysed by* Mr. E. W. T. JONES, *F.C.S., Public Analyst for Wolverhampton, South Staffordshire, &c.*

NOTE.—Where blanks are left the items have not been estimated.

COLUMN No. I.	II.	III.	IV.	V.	VI.	VII.
Geological Formation and Place from which each sample was taken	Total solid matter dried at 100° Centigrade	Nitrogen as Nitrates	Chlorine	Hardness: Temporary	Hardness: Permanent	Hardness: Total
	Grains per gallon	Grains per gallon	Grains per gallon	Degs.	Degs.	Degs.
A *From drift formation in Tame and Anker Valleys.* (Procured by Abyssinian Tube Test Wells.)						
No. 1. From 'Staffordshire' Moor 10 ft. below surface	47·60	0·542	2·100	18·34	16·00	34·34
No. 2. From 'Warwickshire' Moor 10 ft. below surface	38·08	1·522	1·960	12·61	14·83	27·44
No. 3. From No. 8 Test Well at Coton 21 ft. below surface	20·02	0·735	1·190	3·13	8·26	11·39
No. 4. From No. 9 Test Well at Coton 40 ft. below surface	29·68	0·682	0·840	10·94	10·94	21·88
No. 5. From No. 10 Test Well at Coton 37 ft. below surface	30·24	0·857	0·840	11·50	10·38	21·88
No. 6. From No. 12 Test Well at Coton 13 ft. below surface	24·64	0·490	0·980	8·79	9·84	18·63
B *From Springs and Wells in the Marl Measures—*						
No. 7. From Rising Main of Union Workhouse	43·40	—	3·080	11·03	18·63	29·66
No. 8. From Spring on Mr. Neville's Estate, Haselour	38·78	0·612	1·120	5·36	15·41	20·77
No. 9. From Well at Hints Hill	29·40	0·735	1·330	13·02	14·42	27·44
No. 10. From Mr. Thos. Johnson's Well at Hopwas	29·40	1·295	2·100	7·21	8·26	15·47
C *From Springs in Water Stone Rocks of New Red Sandstone formation—*						
No. 11. From Bore Hole at Bole Hall	47·95	—	2·170	8·75	17·58	26·33
D *From Springs and Wells in Conglomerate Beds of New Red Sandstone Formation—*						
No. 12. From Large Spring at foot of Hopwas Wood	29·40	—	2·100	9·12	7·40	16·52
No. 13. From Spring in Hopwas Wood west of Canal	26·60	—	2·450	9·10	6·90	16·00
No. 14. From Spring about half a mile north of No. 12	26·95	—	2·170	6·36	5·69	12·05
No. 15. From Woodhouse Well	49·00	—	3·500	17·56	11·00	28·56
No. 16. From Hopwas Toll-gate Well	20·86	0·647	1·330	2·18	7·21	9·39

Column No. I.	II.	III.	IV.	V.	VI.	VII.
				Hardness		
Geological Formation and Place from which each sample was taken	Total solid matter dried at 100° Centigrade	Nitrogen as Nitrates	Chlorine	Temporary	Permanent	Total
	Grains per gallon	Grains per gallon	Grains per gallon	Degs.	Degs.	Degs.
E *From Spring in Permian Measures of New Red Sandstone formation*—						
No. 17. From Griffin Spring at Hints	21·28	0·385	1·190	7·19	4·20	11·39
F *From Surface Streams and Canal*—						
No. 18. From Coventry Canal at Hopwas	23·10	—	2·240	6·16	7·00	13·16
No. 19. From River Tame	40·95	—	3·430	7·28	12·40	19·68
No. 20. From Crane Brook	19·60	0·262	1·120	2·18	7·21	9·39
No. 21. From Hammerwich Water	17·92	0·175	1·330	2·19	9·31	11·50
No. 22. From Bourne Brook below junction with above	19·88	0·245	1·260	2·67	7·73	10·40

Huntington Pumping Station of South Staffordshire Waterworks.
Collected from Mr. Vawdrey, C.E.

Surface of shaft 528 feet above O.D.; water rose to 500 feet above O.D. level before pumping.

		Ft.	In.
Red marl		9	0
Grey sandstone		31	0
Slightly micaceous sandstone		16	0
Rather coarse grey micaceous sandstone with pebbles		38	6
Quartzite pebbles		0	6
Conglomerate, loose		15	0
Massive compact conglomerate		3	0
Fine-grained sandstone, few pebbles		7	0
Micaceous purple and grey-striped sandstone, few pebbles		9	0
Fine-grained grey sandstone		15	0
Purple and grey fine-grained sandstone		9	0
Massive conglomerate, with vein quartz pebbles		30	0
Boring.			
Hard conglomerate		3	0
Conglomerate with partings (water)		8	0
Light grey sandstone with pebbles and water		6	0
Hard conglomerate		1	0
Mild grey sandstone (water)		6	3
Hard conglomerate		0	9
Mild grey sandstone (water)		6	0
Hard grey sandstone, sop partings, pebbles		5	6
Hard conglomerate, sandstone partings		7	0
Hard sandstone and conglomerate (water)		8	2
Soft red and grey shale	Coal-measures:	1	3
Soft grey shale	Sloping 1 in 12	1	5
Soft shale	to the N.N.W	0	7
Soft grey and red shale (little coal)	to the shafts	3	7
Soft light grey shale	of the Cannock	6	8
Coal.	Chase and Hun-	1	7
Soft grey shale	tingdon Col-	2	6
Black shale	lieries.	1	6
		253	3

Section of Borehole in Sherbrook Valley.
By Mr. W. Wynn Kenrick, *C.E., Rugeley.*

Ft.	In.		Ft.	In.
		Pebble Beds.		
327	5	Gravel and sand	297	0
		Light sandstone and pebbles	20	6
		Sandstone	9	11
		Coal-measures.		
		Marl, &c.	3	6
		Rocky marl	10	6
		Marl, &c.	13	6
		Reddish clunch	3	0
		Red marl	3	6
		Light band	4	0
		Hard red rock	2	0
		Light bind	2	3
		Marl beds, &c.	4	0
		Clunch with marl beds	11	3
		Rocky bind with marl	3	0
		Hard rock	1	0
400	3	Red rock and clunch	9	9
		Blue and mixed ground	8	3
		Grey rock	1	10
		Black clod	2	6
418	4	Coal	5	6
		Sloam and bind	5	2
		Stone band	1	3
		Dark band	2	0
		Dark blue bind	10	6
		Ironstone	0	4
		Clunch and clod	2	9
		Ironstone	0	6
		Blue bind	8	0
		Black clod and with ironstone	6	6
		Lighter stone bind	8	0
		Stone bind, with ironstone	2	6
		Light rock	2	6
		Light blue bind	4	0

Ft.	In.		Ft.	In.
		Light blue bind, with ironstone	7	3
		Hard light rock	2	3
		Blue bind, with ironstone	6	6
		Blue clunchy bind	3	0
		Fireclay	2	6
		Blue bind	8	6
		Stone bind	17	0
		Hard light rock	1	6
		Blue band and ironstone	10	6
		Black bat and coal	2	0
		Light blue bind	8	0
		Light rock	1	0
		Stone bind	12	4
565	2	Coal (Two partings)	8	7
		Light bind	6	6
		Ironstone	1	6
		Light rock	3	0
		Strong blue bind	16	3
		Ironstone	0	3
		Blue clunch	7	9
		Ironstone	0	3
		Strong blue bind and clunch	5	9
		Ironstone	0	3
		Blue clunch	8	0
		Coal	2	1
		Fireclay	2	0
618	1	Coal	3	6
621	1	Fireclay	3	0
			621	1

Abstract.

	Ft.	In.
Loose Bunter conglomerate	297	0
Sandstone	30	5
Coal-measures	293	8
	621	1

Geological Section of Artesian Trial Well for the Stafford Corporation Waterworks, Berkswich Site.

Surface level 3 feet above canal.

Well is 8 feet diameter, and 30 feet in depth; a cast-iron tube is carried through it, of $6\frac{1}{2}$ inches internal diameter and $8\frac{1}{2}$ inches external, to $2\frac{1}{2}$ feet below the shaft; from the base of the pipe a 6-inch chisel boring was carried to a depth of 195 feet from the surface.—E. Timmins, October 1881.

Ft.	In.		Ft.	In.
29	0	Gravel	29	0
31	0	Red sandstone	2	0
146	6	Bunter conglomerate	115	6
155	0	Tough red marl	8	6
195	0	Calcareous red marl	40	0
			195	0

Stafford Corporation Waterworks Trial for Water at Stafford Common.

Ft.		Ft.
217	Keuper marl	217
263	*Rock salt*	46
283	Keuper marls	20
295	*Rock salt*	12
770	Keuper marls	475
		770

The Saltworks at Shirleywich are four miles to the E.N.E., and are also in the Keuper marls, but are separated from the extension tract ranging from Stafford, by Stafford and Enson Moors, to the country west of Stone, by an important north and south fault, which throws up the small coalfield of Moddershall, near Stone, and the more important coalfield of Cannock Chase. The throw of this fault is equal to the vertical thickness of the Keuper marls, Keuper sandstones, and Bunter pebble beds or its maximum point, or not less than 1,500 feet. It ranges through Baswich and Sandon, at the latter place being about a mile to the west of the Enson Moor borings. The first of these was made in 1847 in search of coal, and water overflowed at the surface, which is stated to have been used for cooking and drinking, but from the experience of the boreholes since put down by the Stafford Corporation, there is little doubt the water was largely impregnated with salt.

Enson Moor, Stafford Corporation Boring, 1887.

Ft.	In.		Ft.	In.
		Clay	17	6
		Loamy sand	7	6
39	0	Gravel (400,000 gallons of water in 24 hours)	14	0
		Red marl	35	0
78	9	Sand	4	9
			78	9
		Blue and rock marl	17	3
		Blue and red rock marl (gypsum)	9	0
		Jointy blue and red rock marl with veins of gypsum (800,000 gallons of water in 24 hours)	20	4
		Red rock marl (gypsum)	50	8
			97	3
176	0	*Rock salt*	0	6
		Red rock marl (gypsum)	84	3
		Red rock marl	69	0
		Red and grey rock marl	8	10
		Blue and red rock marl (gypsum)	113	4
476	9	Blue and red rock marl	24	10
			300	9

Ft.	In.		Ft.	In.
		Red sandy marl	4	7
485	4	Grey sandstone (water overflowed)	4	0
		Red sandy marl	22	0
		Grey sandstone	6	0
		Red sandy marl	39	3
		Red and grey sandstone	24	9
		Red sandstone	13	9
		Red and grey sandstone	110	5
		Grey sandstone	19	7
		Red sandstone	3	0
		Grey sandstone	19	1
		Red sandstone	52	5
		Grey sandstone	13	2
		Red "	10	8
		Red "	5	0
		Red and grey sandstone	10	1
		Red sandstone	8	0
850	4	Grey "	7	10
		Red "	3	8
		Red sandy marl	2	0
		Red and grey sandstone	1	0
		Red marl	0	6
865	8	Grey sandstone	8	6

Enson Moor Boring of 1846.

Ft.	In.		Ft.	In.
1	0	Soil	1	0
4	0	Clay	3	0
64	6	Marl	59	6
65	3	Blue rock	0	9
89	6	Rock and red marl	24	3
90	6	Blue clump binds	1	0

Ft.	In.		Ft.	In.
94	0	Rock and rock marl .	3	6
95	0	Light rock	1	0
124	0	Rock marl (110 to 125–6 jointed full of water).	29	0
164	0	Rock marl and plaster .	40	0
173	0	Hard red rock . .	9	0
179	6	Rock marl and plaster .	6	0
180	6	Blue rock and plaster .	1	0
183	0	Brown gristly rock .	2	6
193	0	Rock and rock marl .	10	0
193	6	Salt rock	0	6
210	0	Rock, rock marl, and plaster	16	6
37	0	Hard red and gristly rock	27	0
238	0	Blue rock	1	0
240	0	Red and gristly rock .	0	0
243	0	Rock marl	3	0
267	0	Red and gristly rock .	25	0
268	6	Hard grey rock . .	1	6
273	6	Hard red ,, . .	5	0
278	6	Hard brown Greldon .	5	0
283	0	Red rock and plaster of Paris	4	6
284	6	Blue rock	1	6
286	6	Hard red rock . .	2	0
292	6	Mottled rock . . .	6	0
295	6	Hard red and gristly rock	3	0
300	0	Red and mottled . .	4	6
301	6	Hard blue rock . .	1	6
316	6	Hard mottled rock .	15	0
317	6	Hard light rock . .	1	0
319	6	Blue mottled rock . .	2	0
321	0	Hard light rock . .	1	6
322	0	Light and mottled rock	2	3
324	3	Hard light rock . .	2	3
332	9	Blue and mottled rock .	8	6
340	3	Red and mottled ground	7	6
341	6	Hard light rock . .	1	3
351	0	Red and mottled ground	9	6
356	0	Blue and mottled rock .	5	0
364	0	Blue clunch binds .	8	0
375	0	Red and mottled rock .	11	0
376	0	Blue rock binds . .	1	0
381	0	Red and mottled rock plaster . . .	5	0
382	0	Hard grey rock . .	1	0
383	0	Red rock and plaster .	1	0
384	0	Hard gristly rock . .	1	0
386	0	Red rock and plaster .	2	0
387	0	Blue rock	1	0
390	0	Dark red rock . .	3	0
392	0	Hard gristly rock . .	2	0
392	8	Blue rock	0	8
393	8	Hard pebbly rock . .	1	0
403	8	Blue rock and rock binds	10	0
419	2	Dark red rock . .	15	6
422	2	Light gristly rock .	3	0
424	2	Brown rock	2	0
426	2	Dark red rock . .	2	0
428	8	Strong blue rock . .	2	6
429	8	Blue binds . . .	0	6

Ft.	In.		Ft.	In.
436	4	Dark red and gristly rock	7	2
436	6	Blue binds	0	2
439	6	Blue on mottled ground	3	0
441	0	Dark red rock . .	1	6
441	6	Blue binds . . .	0	6
443	6	Blue rock binds . .	2	0
445	0	Hard gristly rock . .	1	6
455	6	Dark red sandstone .	10	6
457	0	Dark rock binds . .	1	6
459	6	Dark mottled ground .	2	6
460	6	Blue binds	1	0
462	6	Mottled ground . .	2	0
479	0	Dark red sandstone .	6	6
481	4	Red and mottled ground	2	4
482	10	Blue check binds . .	1	6
495	10	Dark red and mottled rock	13	0
501	4	White rock . . .	5	6
538	10	Dark red sandstone .	37	6
550	4	Strong blue rock (water)	11	6
554	4	Hard red sandstone .	4	0
563	4	White rock (water) .	9	0
564	10	White rock, very hard .	1	6
597	0	Light grey rock . .	22	2
599	0	Strong red rock . .	2	0
602	0	Blue rock	3	0
607	0	Hard white rock . .	5	0
610	0	Blue rock, very hard .	3	0
618	0	Hard red and gristly rock	8	0
622	0	Light blue rock . .	4	0
623	0	Hard red rock . .	1	0
633	0	Light brown rock . .	10	0
636	6	Blue and mottled rock .	3	6
642	0	Red rock	5	6
645	0	Blue ,, ...	2	0
645	6	Hard gristly rock . .	1	6
662	0	Light blue rock . .	16	6
665	0	Hard brown rock . .	3	0
700	0	Light jointy rock . .	35	0
702	0	Light brown rock . .	2	0
706	0	Light rock	4	0
712	0	Light brown rock . .	6	0
714	0	Blue binds	2	0
717	0	Red sandy rock . .	3	0
719	—	Red rock marl, clunch .	2	0
720	—	Light rock marl . .	1	0
721	6	Light rock	1	6
727	6	Hard gristly rock . .	6	0
729	6	Light sandy rock . .	2	0
742	6	Light gristly rock . .	13	0
770	—	Light sand rock . .	27	6
772	—	Red rock	2	0
778	—	White rock	6	0
783	—	Light brown rock . .	5	0
786	—	White rock	3	0
788	8	Red sandy rock . .	2	8
806	0	White rock	17	4
810	2	Blue clunch	4	2
838	11	White rock	28	9
841	2	Binds	2	3
854	2	Strong blue rock . .	13	0

Analyses of Waters from Enson Moor, by Prof. ATTFIELD, *Ph.D., F.R.S., F.I.C., F.C.S. London,* 17 *Bloomsbury Square.*

Date	Chlorine	Grains per Gallon	Common Salt
	From Small Borehole		
Aug. 8, 1886	18·2		29·99
Aug. 31, „	18·5	21 days' pumping	30·8
Sept. 21, „	25·3		42·0
Aug. 4, 1887	35·0		58·0
	Large Borehole.		
March 15, 1887	38·1	overflow	63·0
April 1, „	12·0	? 615 feet	19·75
June 6, „	19·9	overflow	
June 20, „	32·4	„	
June 28, „	35·8	„	
July 29, „	238·0	„	402·75
Aug. 4, „	413·0	„	681·5
Aug. 4, „	392·0	from 600 feet	647·0
Aug. 6, „	336·0	overflow	554·5
Aug. 13, „	371·0	„	612·0

From these analyses it appears that the amount of chlorine increased in the water from the small borehole from 18 grs. per gallon on August 8, 1886, to 35 grs. in August of the present year, the water from the large borehole on June 28, 1887, being identical in quality, viz., 35·8 grs. per gallon. The analyses of these waters show some remarkable variation, the amount of chlorine in the large borehole decreasing from 38·1 on March 15, 1887, to only 12 grs. on April 1, and increasing again to 35·8 on June 28, which would presumably be the amount present before the inburst of weak brine on July 2.

Stafford Potteries Waterworks.

Information from Mr. G. D. HARRISON, *C.E., Engineer to the Potteries Waterworks.*

Works in progress (August 1887) at Hatton Mill, near Eccleshall, about 1¼ mile north of Standon station, and about 3 miles south of Whitmore station.

Two boreholes have been carried out, No. 2 being 250 feet N.W. of No. 1. The level of No. 1 is 35 feet above Ordnance datum, and is carried 417 feet below the surface; No. 2 is 6 feet lower and is carried 480 feet. Water flowed over from the first hole at the rate of 360,000 gallons a day when at a depth of 230 feet, at 417 feet at the rate of 700,000 gallons per day, but after a month this was reduced to 560,000. No. 2 hole yields 700,000 gallons and has abstracted the larger portion of the supply of No. 1, which is now very small. The quality is very good, and is of 11 degrees of hardness; water flowed to the surface when a depth of 120 feet was reached. The section penetrated was as follows:—

Ft.	In.			Ft.	In.
1	0	Soil	Drift	1	0
7	6	Sandy loam	Drift	6	6
13	0	Sand and gravel	Drift	5	6
18	0	Sand	Drift	5	0
89	4	Sandstone		71	4
208	0	Variegated sandstone		118	8
247	9	Red and grey sandstone, pebbles		39	9
292	6	Red and grey sandstone		44	9
347	9	Red and grey sandstone, pebbles		55	3
400	6	Red and grey sandstone		52	9
417	6	Red and grey sandstone, pebbles		17	0
			In progress	417	6

The boring was commenced April 11, 1887, and has a diameter of 12 inches.

Information collected by Mr. T. S. Stooke, *C.E.*, *Shrewsbury.*

1. Sundorne estate, near Shrewsbury. **1***a*. In 1884. **2**. 205 feet. **3**. Well was sunk 25 feet in depth and yielded a considerable quantity of water, which was not found desirable for use; consequently a borehole was put down cased with 5 inch tubes to the depth of 38 feet. The borehole was continued to the depth of 76 feet, 3 inch diameter. **3***a*. No drift way. **4**. Little or no variation. **4***a*. The normal level of water in the well is 4 feet, while that in the borehole is 11 feet. **5**. About 45,000 gallons; the quantity used daily is only that required for farm purposes. **8**. Analysis by Mr. Blunt, M.A.:—There is a reddish turbidity, which quickly settles and leaves the water clear and nearly colourless; the sediment is sandy. No lead, copper, or zinc is present in the water. The following analysis gives the results obtained from the clear water after subsidence:—

	Grains per gallon
Total solid contents	50
Chlorine in chlorides	8·5
Nitrogen in nitrates	0·0
Oxygen absorbed	0·012

These data indicate an entire absence of sewage or other organic matter, but the large amount of solid contents and of chlorine is anomalous, and it was thought desirable to determine the hardness:—

	Degrees
Hardness by Clarke's scale, total	35
Permanent (after boiling for some time)	9½
Temporary by difference	25½

It thus appears that more than 25 degrees of the hardness of the water is due to earthy carbonates, and therefore can be removed by boiling or by a precipitating process with lime; moreover it is generally agreed that temporary hardness is of less importance from a sanitary point of view than permanent. The remaining 9½ degrees of permanent hardness is due to magnesium, not to lime salts, principally to chloride of magnesium, none in sewage. The chlorides present are all, or nearly all, in the form of chloride of sodium; it is clear, therefore, that here the chlorides are of mineral origin. On the whole the water must be pronounced pure and wholesome, but somewhat hard for drinking, and excessively so for domestic use.

9.

7 feet	Soil and clay
3 ,,	Clay with gravel
24 ,,	Clay with stones and sand
38 ,,	New Red Sandstone
4 ,,	Permian
76 feet	

10. Yes. **11**. Yes. **12**. One about 600 yards south. **13** and **14**. No. **15**. No.

Collected by Mr. THOMAS S. STOOKE *from Messrs. Timmins and Son, Runcorn.*

1. Shrewsbury Grammar School, on the banks of the Severn. **1***a.* Sunk in 1881; bored in 1882. **2.** 245·89 feet above Ordnance datum. **3.** Well 114 feet deep, 4 feet 6 inches lined with cast-iron cylinders. Borehole, 171 feet deep from surface, 3 inches diameter. **3***a.* 80 feet. Two in number, 10 feet × 10 feet × 3 feet wide. **4.** Water stands at 74 feet below surface, and is not affected by the quantity of rainfall. **4***a.* 74 feet 5 inches below surface. **5.** Yield, 7,100 gallons per hour; the quantity pumped does not approach this at all. Cannot say what quantity is pumped. **6.** Cannot say. **7.** Cannot say. 89 feet above adjoining river Severn.

		Ft.	In.
9.	1. Red and variegated marl and sandstone	122	0
	2. Dark red sandstone	8	0
	3. Marly sandstone	6	0
	4. Red marl	1	6
	5. Marly sandstone	16	6
	6. Red marl	5	0
	7. Marly sandstone	5	0
	8. Purple marl	4	0
	9. Dark red sandstone	1	0
	10. Purple marl	2	0
	Total depth	171	0

9*a.* No. 9. **10.** No drift. **11.** Surface springs cased out. **12.** One, ⅝ mile to the north, wending E.N.E. to W.S.W. **13.** No. **14.** Cannot say. **15.** No. **16.** The outcrop of the Permian sandstone, in which the above well is sunk, is ¾ mile south.

Lincolnshire:—Gainsborough.

The following are the details of the well and borehole carried out by Messrs. Timmins and Son, Runcorn, for the Local Board Waterworks, acting on the advice of your reporter:—

Surface about 25 feet above Ordnance datum. Well, with cast-iron cylinders, 58 feet, with borehole to 1,100 feet from the surface, tubed down to 737 feet with wrought-iron and cast-iron tubes, the last length being 11⅜ inches internal diameter, lower portion of boring 10¼ inches in diameter. The following is the section:—

	Ft.
Keuper marls	725
Good red sandstone	375

At a depth of 900 feet the borehole began to yield water vigorously. The present yield of the well is about 1,000 gallons per hour, and the combined yield of the well and borehole about 9,000 gallons per hour, or 216,000 gallons per day. Analysis by Messrs. Green, Calvert, and Thompson, Manchester, after seven days' continuous pumping:—

	Grains per gallon.
Total solid matter	66·18
Combined chlorine	1·4011
Permanent hardness	36°
Temporary "	10°
	46°

The saline matter consists of—

	Grains
Chloride of magnesium	1·82
Sulphate of soda and magnesium	21·76
Carbonate of lime " "	9·24
Sulphate of lime	28·02
Organic and combined matter	5·34
	66·18

Cheshire.

Collected by Mr. De Rance *from Mr. A. Strahan, F.G.S.*

1. The Elms, Capenhurst, Cheshire. **1***a*. About 1875. **2.** 100. **3.** 74 feet; diameter 10 feet. 217 feet 6 inches to bottom of borehole. **4***a*. Normal level of water, 64 feet 6 inches from surface. **8.** Highly contaminated with sewage. **9.** ? any drift. Bunter pebble beds, with a bed of marl, 6 feet thick, at 180–186 feet from surface.

Collected from Mr. A. Timmins, *C.E., Bridgwater Ironworks, Chapel Lane Boring, near Prescot.*

Water rose to the surface.

	Ft.	In.
Red 'hackly' sandstone	54	0
Red marl	41	0
Red sandstone	19	0
Red marl	11	0
Light red sandstone	35	0
Red marl	2	0
Light red sandstone	33	0
Fine red sandstone	20	0
Coarse red sandstone	96	5
	311	5

The beds closely resemble those obtained in the lower portion of the Bootle boring, and those from the Warrington Waterworks or Winwick.

The Winwick boring details are as follows:—

Ft.	In.			Ft.	In.	Ft.	In.
31	7	Fine white sand		31	7		
129	0	Fine-grained sandstone		97	5		
172	0	Coarse, compact sandstone, with millet seed grain, and bed of red and grey marl		43	0		
		Shaly marl		10	0		
201	6	Fine-grained millet seed, grained sandstone		19	0		
212	0	Hard rag		11	0		
		Sandy marl		2	0		
226	0	Calcareous sandstone		12	0		
253	0	Marl		22	0		
271	0	Large-grained sandstone		18	0		
		Marl		6	0		
		Soft white sand		22	0		
330	0	Soft brown sand		31	0		
341	0	Red sandstone		11	0		
		Mottled grey marl		11	0		
		Dark mottled marl					
		Marl	Coal-measures	27	0		
		Indurated marl	Coal-measures				
		Grey marl and sand shale	Coal-measures			49	0
		Hard shaly marl	Coal-measures	6	0		
390	0	Hard red marl	Coal-measures	5	0		
		Limestone	Coal-measures	(+)			

Lancashire.

Manchester Wells. Drawn up by Mr. De Rance.

Professor Hull surveyed the Manchester district in 1863, and found at that time 60 or 70 wells, yielding not less than 6 million gallons per day from the pebble beds of the New Red Sandstone, and the Lower Permian Sandstone of Manchester and Salford. He states that the collecting area is now more than 7 square miles, covered with houses

and paved streets, and believes the larger part of this supply is derived from infiltration of the waters of the rivers Irk, Medlock, and Irwell; the great natural filtering properties of the Red Sandstone are shown in its rendering water, but little better than sewage, fit for commercial purposes, and capable of being used in factories, breweries, bleaching and dye works.

The following is an analysis, by Dr. Angus Smith, F.R.S., of water from a deep well on the south side of Manchester, analysed in 1865:—

	Grains per gallon
Chloride of sodium	4·83
Sulphate of soda	7·33
Carbonate of soda	7·35
„ lime	9·77
„ magnesium	5·29
	34·57

Assuming that 5 inches of the annual rainfall is absorbed in the 7 square miles referred to, this would give a daily average of (200,000 × 7) 1,400,000, leaving about 4½ million gallons daily infiltrated.

The following information as to Manchester wells has been given by Messrs. Mather and Platt, Salford Ironworks:—

			Gallons per day
Seedley Print Works, well 102′ × 87″, b.-h. 382′ × 18″, 354′ × 18″, 167′ × 18″		yields	750,000
Bagley and Craven	b.-h. 454′ × 18″	„	648,000
Messrs. Aitken	„ 378′ × 18″	„	800,000
Mr. W. Sumner	„ 189′ × 12″	„	46,080
Messrs. Rylands and Son	„ 312′ × 12″	„	90,720
Mr. B. D. Brookes	„ 259′ × 12″	„	86,400
Salford:—			
Salford Ironworks	„ 212′ × 18″	„	50,000
Messrs. Thomas and Chadwick	„ 432′ × 12″	„	50,000
Mr. J. J. M. Worrall	„ 486′ × 18″	„	480,000
Cornbrook:—			
Messrs. Roberts, Dale, and Co.	„ 178′ × 9″	„	30,000
Flixton:—			
Messrs. A. and J. Stott	„ 234′ × 12″	„	317,520
High Broughton:—			
Messrs. Chadwick and Taylor . well 75′ × 10″	„ 671′ × 15″	„	800,000
Patricroft:—			
Messrs. Ermen and Roby	„ 315′ × 18″	„	100,800
Cheadle:—			
Convalescent Hospital	„ 145′ × 12″	„	55,200

Information obtained in 1878.

Messrs. Worrall, Dyeworks, b.-h. 327′, yields 384,480 gallons per day.

Messrs. Worrall, Ordsall, well b.-h. 460′, yielded 717,120 gallons for twelve months, brackish.

Messrs. Hoyle's Works, Mayfield, 356′ 5″ { New Red Sand, 143 feet 4 inches. / P. marls . 153 „ 9 „ / L. P. S. . 59 „ 4 „ }

Collyhurst Sand Delf, exhausted by 12 hours' pumping.

Salford:—

Charlton's Works, well 70′, and b.-h. (?), (150 yards from Boddington's Brewery), yielded 348,000 gallons in 16 hours.

Strangeways:—

Boddington's Brewery yielded 55,840 gallons in 16 hours.

Salford:—

Messrs. Bury's Dyeworks, 300 feet, yielded 353,240 gallons in 16 hours.

Messrs. Moseley's Dyeworks (¼ mile from Bury's) yielded 66,240 gallons in 16 hours.

Smith's (late Joule's) Brewery, 618 feet, with chamber in New Red Sandstone; two pumps yield 137,000 gallons; water level, that of the Irwell. New Red, 468 feet; marls, with limestone, 120 feet; sandstone, with water and clay, 30 feet.

Broughton Road Paper Works, 720 feet, yield 144,000 gallons. Drift and New Red Sandstone, 240 feet; Permians, 150 feet; hard bands, 120 feet.

Medlock Vale Works, 761 feet; water overflows. Gravel, 26 feet; New Red Sandstone, 23 feet; Permian marls, with bands of gypsum and limestone, 246·3; New Permian sandstone, 375·11; Coal-measures, 90 feet.

The following information has also been obtained from journals at Messrs. Mather and Platt's, Salford Ironworks, Manchester:—

Cornbrook Wells.

Bull's Head Brewery.—Surface level about 100 feet above Ordnance. Well 19 feet 6 inches. No water met with.

Boring, $12\frac{1}{2}$ to 172 feet from surface, in red sandstone; the surface is cellar-level, about 90 feet above Ordnance datum.

'Rest levels' of the water in the borehole were—

At 40 feet 6 inches from level of cellar	10 feet	6 inches.
" 166 " " "	16 "	10 "
" 172 " " "	21 "	7 "

Test pumping of 32 gallons per minute reduced water to 44 feet from the cellar-level, or probably (90 − 44) 46 feet above Ordnance datum.

Roberts, Dale, and Co.—Well, 62 feet 8 inches. Boring to 241·4, 9″ diameter. Hard fine-grained red and white sandstone.

Lawrence O'Neild.—Well, 36 feet deep; surface-level about 98 feet, 12″ boring.

	Feet from surface
Sandstone with pebble to	165
Hard red sandstone to	258
Water-level at 69′ 6″ stood at	33
" " 258′ 0″ "	37

Twelve hours' test gave 32,468 gallons and lowered water-level to 44·7, or about $53\frac{1}{2}$ feet Ordnance datum; in two minutes after test water rose 5 feet 2 inches in two minutes, or to 58 feet 7 inches above Ordnance datum.

Rylands and Son.—Well 24 feet. Borehole commences at 15″. Surface-level about 80 feet O.D.

Sandstone		at
Red sandstone		" 144 feet 3″ from surface.
Grey sandstone		" 159 " 9″ " "
Red and grey sandstone		" 255 " 0″ " "
Red raddle	2 ft. 6 in.	
Red sandstone		" 336 " 0″ " "

Pumping test gave 63 gallons per minute, and after nine hours could not lower water below top of borehole; normal water level is 12 feet from surface, or 68 feet O.D., reduced by pumping to 54 feet O.D.

Information collected from Mr. R. T. Burnett, *F.G.S.*

1. Well at Messrs. Deakin's Brewery, Broadie Street, Ardwick, Manchester. **1*a*.** About 1881, sunk by Mr. C. Chapman, Salford. **2.** About 150 feet. **3.** Well 35 feet deep, 6 feet diameter. Borehole, $16\frac{1}{4}$ diameter to 110 feet from surface, 13″ to

334 feet, 12″ to 339 feet 6 inches, 11″ to 355 feet, $10\frac{1}{2}$ to the bottom, 489 feet 9 inches from surface. **3a.** None. Shoe of tubes placed at 343 feet from the surface. **4.** Well water stands 22 feet below the surface, the borehole water at 28 feet below. **5.** More than 2,500 gallons per diem.

From surface Ft. In.		Ft.	In.
96 6	Soft red sandstone	25	6
	Fine red clay	1	0
	Fine soft red sandstone	66	0
	Very coarse gritty red sandstone	4	0
	Red clay	35	6
	Loamy red sandstone	1	0
	Red clay and conglomerate		
	Very strong red sandstone		
	Red clay		
	Red sandstone		

Pebble Beds and Permians.

Area west of the Irwell valley fault, and north of the Irwell, three square miles, absorbing 200,000 gallons per day, equals 600,000 gallons. Seedley Print Works. Surface about 136 feet O.D.

		Feet
Drift (boulder clay)		61
Pebble beds (soft red sandstone)		139
Upper Permian	Marls; Sandstone; Beds of limestone	128
Lower Permian	White rock and red sandstone	$12\frac{1}{2}$
Coal-measures		30
		$370\frac{1}{2}$

The probable position of the base of the Lower Permian is 2,000 feet to the north, giving a dip to the south of the surface of the Coal-measures of 10 deg. The water was believed by the late Mr. Binney, F.R.S., to be derived in these wells from the Lower Permian sandstones. Westwards the red marls with fossiliferous limestones are worked at Astley and Bedford Leigh. At Worsley this series reaches a thickness of 131 feet, and contains 52 thin beds of limestone. Eastwards the Lower Permian sandstone increases in importance, and is worked as moulding sand at Collyhurst.

Information collected by Mr. C. E. De Rance *from Messrs. John Bradbury, Clayton Colliery, per Mr. Atherton, M.E., Bolton.*

1. Boring put down by Mr. John Vivian C.E. (North of England Rock Boring Company), at Openshaw, close to the Clayton township boundary, and 100 yards west of the Manchester and Stockport Canal. **1a.** April to December 1878. No. **2.** 250 feet above O.D. **3.** Borehole as follows:—

9	inches diameter to	25	feet from surface.		
8	”	”	49	”	”
$6\frac{3}{4}$	”	”	112	”	”
$5\frac{3}{4}$	”	”	559	”	”
5	”	”	1019	”	”
$4\frac{1}{2}$	”	”	below		

3a. None.

From surface. Ft.	In.	*Drift.*	Ft.	In.
5	0	Soil and sand	5	0
7	0	Large pebbles and sandy clay	2	0
15	0	Brown sandy clay	8	0
33	0	Brown clay	18	0
35	0	Gravelly clay	2	0
36	0	„ „ and pebbles	1	0
		Bunter.		
76	0	Red sandstone, soft, and very red	40	0
82	0	Red shale	6	0
82	2	Coarse red sandstone with pebbles of quartz	0	2
		Permian.		
90	0	Red shale	7	10
90	6	Yellow sandstone	0	6
102	6	Red shale, top unfossiliferous	12	0
102	10	Yellow sandstone	0	4
108	6	Red shale, no fossils	5	8
118	2	„ „	9	8
120	2	Red sandstone	2	0
124	10	Red shale, no fossils	4	8
146	0	„ „	21	2
146	4	Grey sandstone	0	4
147	6	Red sandy shale	1	2
150	0	Red sandstone, very fine	2	6
150	2	Limestone	0	2
151	6	Grey sandstone, soft	1	4
159	6	Red sandy shale	8	0
160	0	Grey sandstone	0	6
163	0	Red shale	3	0
180	0	Red sandstone, thin beds of shale	17	0
182	3	Red sandstone	2	3
184	9	Red shale	2	6
189	3	Red sandstone	4	6
196	0	Red shale	6	9
200	4	Red sandstone	4	4
217	4	Red shale	17	0
218	8	Brown limestone	1	4
220	10	Red shale	2	2
220	11	Gypsum	0	1
223	4	Red shale, with *anthracosiæ ?*	2	5
234	4	„ „ gypsum in shells	11	0
239	6	„ „ large shells	5	3
243	6	Brown and grey shelly limestone, consisting of shale	4	0
244	6	Shells in red shale	1	0
244	10	Grey limestone	0	4
257	6	Red shale with their bands full of shells	12	8
258	0	Grey shale with shells	0	6
267	0	Red shale, with many thin bands, full of shells	9	0
267	3	Reddish-brown massive limestone	0	3
279	0	Red shale, with some shells	11	9
282	0	Red shales, thin bands of brown fine sandstone	3	0
282	9	Fine hard grey sandstone	0	9
285	0	Sandstone conglomerate	2	3
292	6	Red sandstone, fine and soft	7	6
301	6	„ „ coarse	9	0
310	0	„ „ very soft	8	6
319	6	„ „ rather coarse	9	6
333	6	„ „ soft and jointed; water disappeared	14	0
339	6	„ „	6	0
345	0	„ „ finer, thin bed of shale	5	6
347	0	Red and grey sandstone, fine and mottled shale, hard	2	0

Ft.	In.		Ft.	In.
375	0	Red (grey mottlings), fine-grained sandstone	28	0
386	6	Red sandstone, coarse	11	6
398	0	" " "	11	6
435	6	" " very coarse	37	6
470	6	" " rather coarse	35	0
499	6	" " fine-grained	29	0
542	0	" " " " coarse bands	42	6
554	0	" " " " " "	12	0
583	6	" " a little coarser	29	6
601	2	" " " harder	17	8
642	9	" " " softer	41	7
644	3	" " mottled	11	6
673	6	" " red and soft	29	3
691	0	" " very soft and fine-grained	17	6
733	0	" " coarser	142	0
745	0	" " stronger	12	0
1,036	6	" " soft	291	6
1,037	0	" " "	0	6

Upper Coal-measures.

Ft.	In.		Ft.	In.
1,042	0	Dark grey shale	5	0
1,058	0	Dark grey gritty shale (dipping 1 in 3)	16	0
1,075	0	Purple shale	17	0
1,080	0	Dark grey shale, rather gritty	5	0
1,080	6	Grey sandstone	0	6
1,084	0	Purple shale	3	6
1,088	0	Dark grey and purple sandy shale	4	0
1,101	0	" " sandstone	13	0
1,147	7	Purple shale, very dark purple	46	6
1,149	11	*Grey earthy limestone*	2	4
1,150	1	Grey shale	0	2
1,177	2	Purple shale	27	1
1,186	6	*Grey limestone*	9	4
1,192	6	Purple shale, with green shale	6	0
1,194	2	*Grey limestone*	1	8
1,196	0	Grey and purple shale	1	10
1,196	4	Purple shale	0	4
1,199	0	*Brown limestone*	2	8
1,201	8	Purple shale	1	8
1,205	0	*Grey limestone*	4	4
1,214	4	Purple shale	9	4
1,219	4	Red shale and limestone breccia	5	0
1,224	4	Variegated shale	5	0
1,224	10	Limestone breccia	0	6
1,230	4	Red shale	5	6
1,232	2	*Limestone* earthy	1	10
1,237	2	Variegated shaly clay	5	0
1,237	8	*Grey limestone*	0	6
1,238	2	Shale	0	6
1,239	8	*Grey limestone*	1	6
1,241	2	Purple shale	1	6
1,241	11	*Limestone*	0	9
1,242	2	Shale.	0	3
1,243	8	*Grey limestone*	1	6
1,248	2	Shale and clay	4	6
1,259	8	Variegated purple shale	11	6
1,265	2	Purple shale, lenticular ironstone	5	8
1,266	2	Red sandstone, very fine	1	0
1,277	6	Red and grey sandstone, very fine	11	4
1,280	9	Purple shale	3	3
1,281	6	Calcareous band, with ironstone	0	9
1,289	6	Sandstone and shale	8	0

Ft.	In.		Ft.	In.
1,299	0	Red and grey sandstone, fine-grained (*Neuropteris* and shale bed)	9	6
1,300	0	Red shale	1	6
			1,300	0

ABSTRACT OF SECTION.

36	0	Drift	36	0
		Bunter red sandstone	40	0
		Red shale	6	0
82	2	Coarse sandstone, marl, quartz, pebbles	0	2
		Permian marls, shale, sandstone, fossiliferous thin limestone, and gypsum	200	7
285	0	Conglomerate sandstone	2	3
1,037	0	Permian sandstone	752	0
1,330	0	Upper Coal-measures, shales, sandstone, and Ardwich limestones (from a few inches in thickness to 9 feet 4 inches)	263	0
			1,330	0

The dip of the Permian was 1 in 8; that of the underlying Coal-measures nearly 1 in 3.

Messrs. Stanning's Bleach Works, Leyland, near Preston.
Messrs. Timmins, Runcorn, Contractors.

	Feet.
Drift sand	54
Marl streaked with gypsum	216
	270

It is not certain whether these marls are referable to the Keuper marls or to the Glacial boulder clay.

Section of well and boring made by the Leyland Local Board near the 'Seven Stars' Inn, but abandoned by them.

		Feet.
Well 6 feet diameter	Stiff boulder clay	9
	Stony clay and gravel	24
Boring	White sandstone, marl partings	147
		180

The surface of the ground is 91 feet above the mean sea-level, and the rock surface is therefore 36 feet below it. Water occurred at 51 feet from the surface, and again at 120 feet; it rose to 30 feet from the surface, or 61 feet above Ordnance.

At Messrs. Bashall's Mill at Farington the following section has been proved:—

	Ft.	In.
Red clay	11	0
„ sand	29	0
Fine gravel	26	0
Red sand	14	0
Red clay	1	6
Fine gravel	5	0
Red clay	26	0
	112	6

Cop Lane Well and Boring, Penwortham, near Preston, Lancashire, 1887. *Contractors, Messrs. A. Timmins, Runcorn, for Mr. Rawstorne, Howick Hall, Preston. Well* 60 *feet. Stated to be Boulder Clay and Sand Boring,* 100 *feet in Pebble Beds of New Red Sandstone. Trial yields* 26,000 *gallons per day.*

ANALYSIS OF WATER. *By* MR. A. TIMMINS.

Appearance and colour—A dull green cast and turbid look. With standing has a rusty red deposit.

Reaction	Alkaline
Poisonous metals	Traces of iron

	Grains per gallon.
Total solids on evaporation at 212° F.	39·000
Combined chlorine	3·100
Equals common salt	5·180
Nitrates equal to potassium nitrate	·1804
Sulphuric acid	4·060

ORGANIC MATTER.

	Grains per gallon.
Oxygen absorbed in 35 minutes	·0100
„ „ 5 hours	·0180
„ permanent	0·360
Permanent hardness in degrees (Clarke)	17·152
Temporary „ „ „	10·848
Total	28·000

The water on exposure to the air assumes a turbid appearance and deposits a reddish-coloured matter: this, on analysis, proved to be iron. It no doubt occurs in solution as carbonate of iron and on exposure to the air takes up oxygen and settles out as iron oxide; after the deposit has settled the water is perfectly clear and bright.

Spring from Glacial Sand at Penwortham, near Preston, 25 *feet above Ordnance datum. Analysis of Water from St. Mary's Well (a flowing spring). Collected Aug.* 20, 1887. *Analysed by* MR. A. TIMMINS, *Runcorn.*

IN PARTS PER 70·000.

	Grains per gallon.
Total solids on evaporation at 212° F.	55·200
Combined chlorine	6·000
Equals common salt	9·882
Nitrates	1·403

Permanent hardness	27·27°	(Clarke)
Temporary „	4·09	„
Total	31·36	

ORGANIC MATTER.

Oxygen absorbed in 1 hour	·010	(Clarke)
„ „ 20 hours	·022	„
„ stood well	·044	

Nessler solution, a thick white flocculent ppt.

Appearance of water in 2 ft. tube very clear and bright; reaction alkaline; smell and taste none perceivable. The water showed a slight trace of iron when concentrated.

This is a fairly good drinking water; the solids are high and it is very hard; the solids are however of a harmless nature, consisting principally of carbonates and sulphates of lime.

Coal-measures and Millstone Grit Borings.

Collected from Mr. E. Muir, *C.E., Manchester. Well* (50 *feet by* 8 *feet*) *and Boring* (1 *ft.* 2 *in. diameter*) *at the Canal Wharf, near Bury Station, for the Lancashire and Yorkshire Railway Company, August* 1885.

Ft.	In.		Ft.	In.
8	0	Gravel	8	0
51	0	Light red rock	43	0
69	0	Reddish grey rock	18	0
75	0	Grey rock	6	0
88	0	Light grey rock	13	0
89	0	Clay parting	1	0
90	0	Yellow rag rock	1	0
110	0	Light grey rock	20	0
113	0	Reddish grey rock	3	0
118	0	Grey rock brownish	5	0
120	0	Clay	2	0
122	0	Grey rock brownish	2	0
126	0	Reddish grey rock	4	0
127	0	Cank	1	0
146	0	Grey rock reddish	19	0
158	0	Stone band	12	0
160	0	White metal	2	0
163	0	Stone bind	3	0
183	0	White ashlar with bands of spar	20	0
184	0	Stone bind and black shale	1	0
			184	0

Large adjacent quarries were formerly worked, and were given up, owing to the water met with; old coal workings probably exist, under the area, worked long since, at a considerable depth from the surface. Pumping the water from the above boring considerably diminished the yield of several wells to the west; the most important of these has since been deepened with good results.

Section of a Boring made at Withnell Moor by the Diamond Boring Company, Limited, 1874 *and* 1875, *for Messrs. Ascroft and Sykes, Preston.*

Diameter of boring commenced 8 in. diameter, terminating with a diameter of 3 in.

No.		Ft.	In.
1.	Peat	3	0
2.	Coarse grit rock	80	0
3.	Black shale	3	0
4.	Coal	0	2
5.	Bastard fire-clay	5	0
6.	Flag grey laminated rock with black floors	198	4
7.	Blue metal with grey floors	5	6
8.	Grey laminated or flag rock with black floors	20	6
9.	Blue metal with grey floors	29	0
10.	Hard grey rock with blue floors	24	0

No.		Ft.	In.
11.	Blue metal with grey linsey	38	5
12.	Grey rock	4	$4\frac{1}{2}$
13.	Blue metal	25	3
14.	Grey rock	5	5
15.	Blue metal with grey rock bands	70	11
16.	Dark shale, nearly black	25	7
17.	Grey linsey flooring	0	6
18.	Dark shale with traces of grey	35	8
19.	Grey rock with blue floor in middle	4	5
20.	Dark shale with traces of grey	6	2
21.	Grey burr stone, flinty	1	3
22.	Dark shale with traces of grey	55	0
23.	Dark sandy shale with traces of grey	112	6
24.	Black shale with traces of felspar	39	6
25.	White rock	6	6
26.	Grey rock	11	6
27.	Black shale	2	6
28.	Dark sandy shale with white floor	5	6
29.	Grey rock with traces of black shale	21	3
30.	Coarse white rock with traces of black shale	6	3
31.	Grey laminated rock with black shale floors	36	0
32.	Black shale with traces of grey	11	0
33.	Grey rock	4	0
34.	Black shale with traces of grey	46	0
35.	Grey rock with traces of mica	8	0
		951	$11\frac{1}{2}$

Mr. Belsham, C.E., formerly of the Diamond Rock Boring Co., who had charge of the work, states that water rose to about 30 feet from the surface, and its level was maintained during the whole of the work. He considers that the water escaped through a fissure at that level.

Walton-le-Dale Local Board Well, at the Canal Summit-level, Brindle. Well constructed by Mr. Tilley, London. Boring by the North of England Rock Boring Company, 1876. *Site and original works suggested by the Reporter to your Committee. Headings have since been driven by the advice of Mr. W. Wrennal, C.E., Liverpool, by Mr. T. D. Lewin, of Manchester.*

The following is the section penetrated:—

	Ft.	In.
Drift:—		
Loam	1	0
Clay	17	0
Sand and gravel	20	0
Boulders and shale	6	0
Third Millstone Grit:—		
Black shale	4	0
Hard black rock	1	0
Grey sandstone	2	0
Sandy black shale	8	0
Grey and red sandstone	17	0
Black shale	6	6
Grey sandstone	11	0
Sandstone and shale	4	0
Black shale	2	6
Grey sandstone	14	$7\frac{1}{2}$

Appendix by W. Whitaker, B.A., F.R.S., F.G.S., Assoc. Inst. C.E.

Chronological List of Works referring to Underground Water, England and Wales.

My first attempt at a subject-list of geological works, for England and Wales, was that on 'Coast-Changes and Shore-Deposits,' in the 'Report of the Committee for inquiring into the Rate of Erosion of Sea-Coasts, &c.,' printed in the British Association's volume for 1885. A second attempt is now made for the Underground Water Committee.

In the following list, besides such papers as deal specially with the subject, there are noted those that give sections of wells or borings for water, or analyses of well-waters, and that refer to springs (the outflow of underground water); but the many works dealing purely with mineral waters (from the medical point of view) are not noted, that subject having a large literature of its own, deserving of separate treatment. The Reports of this Committee have also been omitted.

Although the entries number 556, yet the writer is well aware that there are probably many omissions, and he would be obliged by the notification of any. A number of titles have been kept back as uncertain.

1656–91.

Aubrey, J. The Natural History of Wiltshire. (Edited by J. Britton, 4to. *Lond.* 1847.) Refers to Springs.

1664.

Lawrence, T. Mercurius Centralis; or, a Discourse of Subterranean Cockle, Muscle, and Oyster-shels found in the digging a well at Sir William Doylie's, in Norfolk. 12mo. *Lond.* Another ed. in 1688.

1669.

Jackson, Dr. W. Some Enquiries concerning the Salt-Springs and the Way of Salt-making at Nantwich in Cheshire. Answered. *Phil. Trans.* vol. iv. no. 3, p. 1060.

1679.

Rastell, Dr. T. An Account of the Salt Waters of Droytwich in Worcestershire. *Phil. Trans.* vol. xii. no. 142, p. 1059.

1684.

Lister, Dr. M. Certain Observations of the Midland Salt-Springs of Worcester-shire, Stafford-shire, and Cheshire. *Phil. Trans.* vol. xiv. no. 156, p. 489.

1728.

Lewis, Rev. J. An Account of the several Strata of Earths and Fossils found in sinking the mineral Wells at Holt. *Phil. Trans.* vol. xxxv. no. 403, p. 489.

1730?

Collinson, P. (communicated by). A Letter from the King's Officers . . . giving an Account of what they met with in opening an antient Well near Queenborough in Kent. *Phil. Trans.* vol. xxxvi. p. 191.

1732 ? (or 3 ?).

Atwell, J. Conjectures upon the Nature of Intermitting Springs. (Brixham.) *Phil. Trans.* vol. xxxviii. p. 301.

1738 ?

Cooke, B. An Observation of an extraordinary Damp in a Well in the Isle of Wight. *Phil. Trans.* vol. xl. no. 450, p. 379.

1744.

Hankewitz, A. G. An Examination of the Westashton Well-waters. *Phil. Trans.* vol. xli. pt. 2, p. 828.

1757.

Matthews, E. An Account of the Sinking of a River near Pontypool in Monmouthshire. *Phil. Trans.* vol. xlix. pt. 2, p. 547.

1782.

Anon. [On Sheppey and a Well at Sheerness.] *European Mag.* vol. ii. p. 430.

Englefield, Sir H. C. Account of the Appearance of the Soil at opening a Well at Hanby in Lincolnshire. *Phil. Trans.* vol. lxxi. pt. 2, p. 345.

1784.

Cullum, Sir J. The History and Antiquities of Hawstead in the County of Suffolk. (Account of Well at Hardwick, p. 230.) 4to. *Lond.* Ed. 2 in 1813.

Page, Sir T. H. Descriptions of the King's Wells at Sheerness, Languard Fort, and Harwich. *Phil. Trans.* vol. lxxiv. p. 6.

1785.

Darwin, E. Of an Artificial Spring of Water. (Well, Derby.) *Phil. Trans.* vol. lxxv. p. 1.

1787.

Limbird, J. An Account of the Strata observed in sinking for Water at Boston, in Lincolnshire. *Phil. Trans.* vol. lxxvii. p. 50.

1797.

Polwhele, Rev. R. The History of Devonshire. Vol. i. (Springs, p. 16). Fol. *Lond.*

Vulliamy, B. An Account of the Means employed to obtain an overflowing Well [Norland House, Notting Hill]. *Phil. Trans.* vol. lxxxvii. p. 325.

1798.

Anon. (**C. C.**) Letter on a Plan for forming a Tunnel under the Thames. (Account of Well at Tilbury Fort.) *Gent. Mag.* vol. lxviii. pt. 2, p. 565.

Middleton, J. View of the Agriculture of Middlesex (Water, with Wells). 8vo. *Lond.* Ed. 2 in 1807.

1802.

Pearson, Rev. W. Observations on some remarkable Wells near the Sea Coast at Brighthelmstone, and other Places contiguous. *Journ. Nat. Phil. Chem. Arts*, vol. iii. p. 65.

1809.

Hall, J. [On a Well at Neasden, Willesden.] *Monthly Mag.* vol. xxvii. pp. 453, 454.

1813.

Gough, J. Observations on the ebbing and flowing well at Giggleswich in the West Riding of Yorkshire; with a theory of reciprocating fountains. *Journ. Nat. Phil. Chem. Arts*, ser. 2, vol. xxxv. pp. 178–193; vol. xxxvi. pp. 46–56. From *Mem. Phil. Soc. Manch.* n. ser. vol. ii. pp. 354–363.

Townsend, Rev. J. The character of Moses established for Veracity as an Historian. 4to. *Bath.* (Wells, pp. 123, 124, 129, 130. Of Springs, 304–315, 418–425.)

1814.

Horner, L. An Account of the Brine Springs at Droitwich. *Trans. Geol. Soc.* vol ii. p. 94.

Longmire, J. B. On the Rise of Water in the Chesswater Mine. *Ann. Phil.* vol. iv. p. 258.

Manning, Rev. O., and **W. Bray**. History and Antiquities of the County of Surrey. (Wimbledon Well, vol. iii. p. 272.) Fol. *Lond.*

Moyle, M. P. Queries respecting the flowing of Water in Mines. *Ann. Phil.* vol. iii. p. 393.

1815.

Storer, Dr. J. On an ebbing and flowing stream, discovered by boring in the harbour of Bridlington. *Phil. Trans.* vol. cv. pt. i. pp. 54–59, and *Phil. Mag.* vol. xlv. p. 432.

1817.

Anon. The ebbing and flowing stream in the Harbour of Bridlington, Yorkshire. *Phil. Mag.* vol. xlix. p. 230.

—— On Ebbing and flowing Springs. *Ibid.* vol. l. p. 267.

Buckland, Rev. Prof. W. Description of a series of Specimens from the Plastic Clay. . . . (Wells, pp, 290, 291). *Trans. Geol. Soc.* vol. iv. p. 277.

Inglis, G. On the Cause of Ebbing and Flowing Springs [Bridlington]. *Phil. Mag.* vol. l. p. 81.

1818.

Phillips, W. Account of the Wells, &c., in W. Robinson's 'History and Antiquities of the Parish of Tottenham High Cross.' 8vo. *Tottenham.*

1822.

Conybeare, Rev. W. D. and **W. Phillips.** Outlines of the Geology of England and Wales . . . (Wells, pp. 24–26, 33, 35, 36, 44, 45, 85, 88, &c.). 8vo. *Lond.*

Sedgwick, Rev. Prof. A. On the Geology of the Isle of Wight. (Harwich Well-sections, pp. 352, 353.) *Ann. Phil.* ser. 2, vol. iii. p. 329.

Young, Rev. G., and **J. Bird.** A Geological Survey of the Yorkshire

Coast. . . . (Ebbing and flowing Spring, Bridlington, pp. 22–24; intermittent Springs, 27, 28.) 4to. *Whitby.* Ed. 2 in 1828.

1824.

Buckland, Rev. Prof. W., and **Rev. W. D. Conybeare.** Observations on the South-western Coal District of England. (Swallow-holes and underground Streams, p. 223; Underground Reservoirs, pp. 292, 293). *Trans. Geol. Soc.* ser. 2, vol. i. pt. ii. p. 210.

Bunbury, Sir H. On the Strata observed in boring at Mildenhall in Suffolk. *Trans. Geol. Soc.* ser. 2, vol. i. pt. ii. pp. 379, 380.

Cragg, J. Account of Well, in Dr. A. Werburgh's 'Sketches of Sleaford.' 8vo. *Sleaford.*

Drew, S. The History of Cornwall. Vol. i. (. . . Wells, p. 509). 4to. *Helston.*

Sabine, J. An Account of the Overflowing Well in the Garden of the Horticultural Society at Chiswick. *Quart. Journ. Sci. Lit. Arts,* vol. xvii. p. 70.

1825.

Davy, Dr. J. Observations on the Temperature of Springs, Wells and Mines in Cornwall. *Edin. Journ. Sci.* vol. iii. p. 75.

1826.

Yeats, T. Section of a Well sunk at Streatham Common. *Trans. Geol. Soc.* ser. 2, vol. ii. p. 135.

1827.

Taylor, R. C. On the Geology of East Norfolk. (Section at Mousehold, Norwich, p. 285, or p. 17 of separate work.) *Phil. Mag.* ser. 2, vol. i. p. 277, and published separately, with a set of papers.

1828.

Report of the Commissioners to Inquire into the State of the Supply of Water in the Metropolis (Well-section, *Lambeth,* pp. 110, 111.) Fol. *Lond.*

1829.

Anon. A short account of the well at Syon House (Isleworth). *Mag. Nat. Hist.* vol. ii. p. 87. Translated in *Journal de Géologie,* t. iii. p. 301 (1831).

Brayley, E. W. On the Existence of Salts of Potash in Brine-Springs and in Rock-Salt. *Phil. Mag.* ser. 2, vol. v. p. 411.

Faulkner, T. Historical and Topographical Description of Chelsea. (Refers to wells.) 8vo. *Lond.*

Moore, Rev. T. The History of Devonshire (Springs, p. 30). 4to. *Lond.*

Phillips, Prof. J. Illustrations of the Geology of Yorkshire . . . Pt. 1, The Yorkshire Coast, 4to. Ed. 2 in 1835, Ed. 3 in 1875 (Wells at Hull, Bridlington, and Vale of Pickering, pp. 65, 66, 84, 280, of Ed. 3).

Thury, Vicomte H. de. Considérations . . . sur la Cause du Jaillissement des Eaux des Puits Forés (Wells at Sheerness and Richmond). 8vo. Paris.

1830.

Henderson, Dr. R. On the General Existence of Iodine in Spring Water. *Phil. Mag.* ser. 2, vol. vii. p. 10.

1831.

Daubeny, Dr. C. Remarks on Thermal Springs, and their Connexion with Volcanos. *Edin. New Phil. Journ.* vol. xii. p. 49.

Henwood, W. J. Facts bearing on the Theory of the Formation of Springs, and their Intensity at Various Periods of the Year. *Phil. Mag.* ser. 2, vol. ix. p. 170.

1832.

Bland, W. Letter recording a Series of Observations on the Rise and Fall of Water in Wells in the County of Kent. *Phil. Mag.* ser. 2, vol. xi. p. 88.

1833.

Henwood, W. J. Observations on the Rise and Fall of Water in some Wells in Cornwall, with brief notices of other matters bearing on the Phænomena of Springs. *Phil. Mag.* ser. 3, vol. iii. p. 417.

1834.

Ure, Dr. A. Analysis of the Moira Brine Spring near Ashby-de-la-Zouche, Leicestershire; with Researches on the Extraction of Bromine. *Phil. Trans.* vol. cxxiv. p. 577.

1835.

Daubeny, Prof. C. On Dr. Ure's Paper, in the Phil. Trans., on the Moira Brine Spring, &c. *Phil. Mag.* ser. 3, vol. vi. p. 321.

Hastings, Dr. C. On the Salt Springs of Worcestershire. *Analyst*, vol. ii. pp. 359–385.

Rose, C. B. A Sketch of the Geology of West Norfolk (Wells, pp. 173, 275). *Phil. Mag.* ser. 3, vol. vii. pp. 171, 274.

1836.

Bannester — [Account of Well at Rushley.] In T. Wright's 'History and Topography of the County of Essex,' vol. ii. p. 634. 4to. *Lond.*

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Gravatt, W. Some Account of several Sections through the Plastic Clay formation in the vicinity of London. *Trans. Inst. C. E.* vol. i. p. 151.

1837.

Buckland, Rev. Prof. W. Geology and Mineralogy considered with Reference to Natural Theology. Wells, vol. i. pp. 563–566; vol. ii. pls. 68, 69. 8vo. *Lond.*

Daubeny, Dr. C. Report on the Present State of our Knowledge with respect to Mineral and Thermal Waters. *Rep. Brit. Assoc.* 1836, p. 1.

Mitchell, Dr. J. An Account of a Well at Beaumont Green in the County of Hertford. *Proc. Geol. Soc.* vol. ii. no. 51, pp. 551, 552.

Richardson, W. Notice of a successful attempt at boring for water at Mortlake. *Proc. Geol. Soc.* vol. ii. no. 48, pp. 449, 450.

Rofe, J. Observations on the Geological Structure of the Neighbourhood of Reading. (Well-section, p. 129.) *Trans. Geol. Soc.* ser. 2, vol. v. p. 127; and *Proc. Geol. Soc.* vol. ii. no. 36, p. 72 (1833).

Taylor, J. Observations on the Strata penetrated in sinking a Well

at Diss in Norfolk. *Trans. Geol. Soc.* ser. 2, vol. v. p. 137, and *Proc. Geol. Soc.* vol. ii. no. 36, p. 93 (1834).

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1838.

Armstrong, W. An Account of Tapping and Closing the Spring of Hot Water, at Mr. Pinch's Brewery, Bath. 8vo. *Bristol.*

1839.

Anon. ? Artesian Well at Saffron Walden, made in 1836. *Essex Literary Journ.* Feb. 15.

Faulkner, T. History of Hammersmith. (Well, p. 13.) 8vo. *Lond.*

Long, H. L. [given as **G.**] On the occurrence of numerous Swallow Holes near Farnham; with some observations on the drainage of the country at the western extremity of the Hog's Back (Well-section). *Proc. Geol. Soc.* vol. iii. no. 62, pp. 101, 102.

Mitchell, Dr. J. On the Wells found by digging and boring in the gravel and London Clay in Essex, and on the geological phenomena disclosed by them. (Refers also to bournes.) *Proc. Geol. Soc.* vol. iii. no. 64, pp. 131–134.

—— On the Foul Air in the Chalk and Strata above the Chalk near London. *Ibid.* no. 65, p. 151.

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Clarke, Rev. W. B. On the Geological Structure and Phenomena of the County of Suffolk, and its Physical Relations with Norfolk and Essex. (Well-sections, pp. 368–383.) *Trans. Geol. Soc.* ser. 2, vol. v. p. 359.

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1841.

Allport, D. Collections illustrative of the Geology, &c., of Camberwell. (Well-sections, pp. 5, 7, 8.) 8vo. and 4to. *Camberwell.*

Clutterbuck, Rev. J. C. A Letter to Sir J. Sebright on the injurious Consequences likely to accrue to a portion of the County of Hertford if the London and Westminster Water Company should carry into effect their project of supplying the Metropolis with Water from the Valley of the River Colne. Pp. 16, plate. 8vo. *Watford* and *London.*

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1842.

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1843.

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Lapidge, S. Description of Strata passed through in sinking an artesian well at the Surrey County Lunatic Asylum, at Springfield, Wandsworth. *Geologist*, p. 20.

1844.

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Smith, W. [Well-sinking.] pp. 80–85 of Prof. J. Phillips' 'Memoirs of William Smith.' 8vo. *Lond.*

1845.

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Report of the Committee, consisting of Dr. H. WOODWARD, Mr. H. KEEPING, *and* Mr. J. STARKIE GARDNER, *appointed for the purpose of exploring the Higher Eocene Beds of the Isle of Wight.—By the Secretary*, J. S. GARDNER.

[PLATES III., IV., AND V.]

THE Tertiary floras which we find represented most abundantly on the continent of Europe are of Upper Eocene, Oligocene, Miocene, and Pliocene age. These are all posterior to our Bagshot, the age during which, in Great Britain and Ireland, the conditions necessary to preserve extensive assortments of forest vegetation ceased to exist. These precise conditions, whatever they may be, seem to have rolled like a vast wave from north-west to south and east, leaving its trail in innumerable fossil floras scattered over a belt extending from the Baltic, through Germany, Bohemia, and the Alps, to the Mediterranean littoral.

In Great Britain and Ireland the Eocenes, from their base upward, whether sedimentary or volcanic, are continually intercalated with fluvia-

tile clays, literally choked with leaves. A remarkable peculiarity, shared by every one of these leaf beds, is that they are almost wholly destitute of any traces of animal life except the disarticulated wings and wing cases of insects. It is difficult to imagine how it has happened that these vast and recurring accumulations of fine silt, well fitted to preserve the most delicate organisms, should not at all events abound with the remains of freshwater fish. They were formed in the beds of rivers of various dimensions, some of great magnitude, and in the higher as well as the lower reaches. Yet throughout the twenty odd years I have been collecting in these at home and abroad, I have never so much as found a fish scale nor aquatic insect in any plant bed, unless newer in age than the Bagshot. It may appear a bold inference to draw, but the only one possible is that freshwater fish did not exist in our area in Eocene times. All other explanations, such as difference in powers of flotation, drifting, decomposition, break down on examination. Plant beds of the same character, but of later date, in France, Germany, &c., abound in fish and insects; and in some cases, as at Céreste, the number of feathers accompanying them seems to indicate that this food supply had speedily led to the development of aquatic bird life. The English Oligocenes are no exception to the rule, and in place of its former almost oppressive absence, they teem with aquatic life in many forms, and scarcely a plant bed thenceforward is unaccompanied with animal remains.

This new state of things begins in our area in the Headon, and partly on this account collecting fossil plants in these higher beds is far from easy. The superabundance of aquatic life, especially mollusca, is antagonistic to the preservation of plants. Most leaves preserve their forms in water for many months, if perfectly undisturbed, and would in time become covered by films of silt, to be compacted eventually into the finely laminated clay which constitutes a leaf-bed. But on a bottom infested with life they would rapidly break up when decay set in, and silt largely mixed with dead shells is not a good medium to preserve them. It is only here and there in the Hampshire Oligocenes that plants are found in good preservation and the patches are small and local, so that, unless a collector happens to be present when they are exposed, their contents become lost. This circumstance always renders it doubtful whether a special search for plants will be rewarded, and disappointment has more often resulted than the reverse. Hence while we have great collections from the British Eocenes, which may teach the succession of vegetation that occupied our area, our Oligocene flora is only represented by small groups of plants in widely scattered collections, so that it is not easy to form an idea of it as a whole.

A former grant enabled the Lower Headon flora of Hordwell to be explored as far as possible, and the present one has enabled us to obtain a satisfactory insight into the newer Oligocene floras of the Isle of Wight. Some account of the former has been given in a previous report. As an illustration of the local distribution of plants in our Oligocenes, I may mention that a large number of specimens of palms from Hordwell were sent to Belgium, a mass of them in a solid matrix having been exposed during a few tides, whilst a foreign collector happened to be visiting the spot. Some pieces of feather palms, obtained on another occasion by Mr. Keeping, have been figured for the Palæontographical Society.

Unlike the Lower Headon, the Middle Headon, an almost purely marine deposit, seems completely barren of plants.

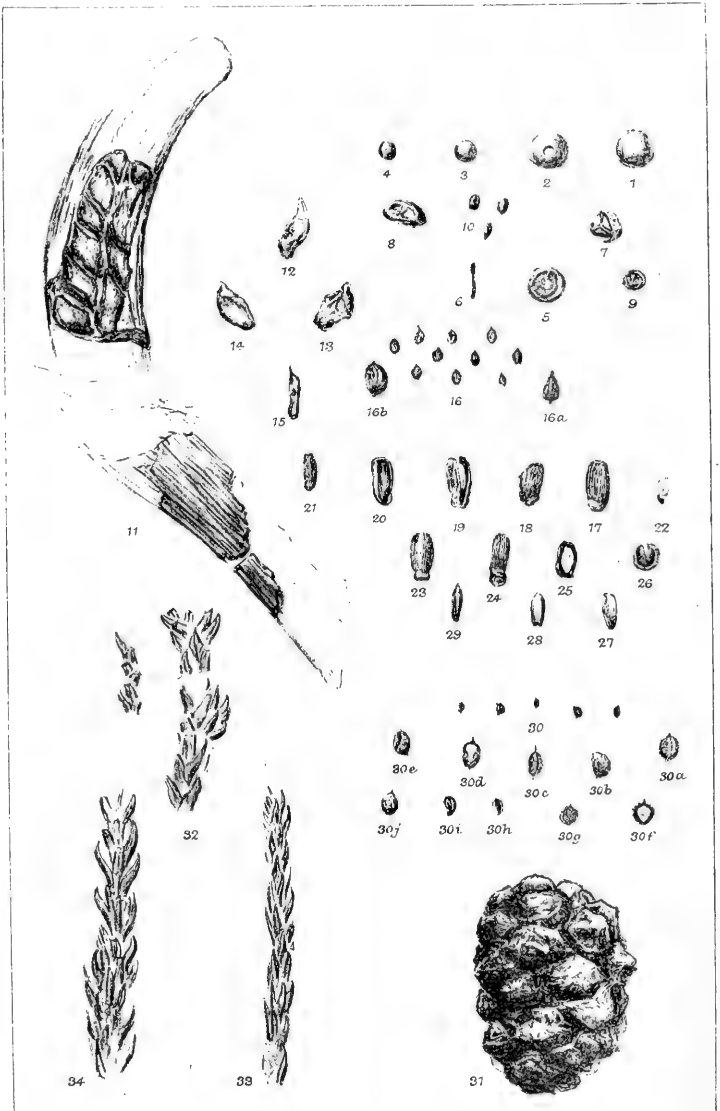
Very few plants are known from the Upper Headon, but a band of clay ironstone above the limestone, also found by Mr. Keeping, occasionally contains beautifully preserved leaves. Examples of these are in the museums at Cambridge and York. It is some years since any have been found, and we have failed to meet with them lately, though we have often made special search.

The Osborne marly clays have undergone a chemical change, leaving them 'mottled,' which has seemingly obliterated all traces of plants, if any existed, though nucules of *Chara* are met with in the limestones of this, as well as of the Bembridge series. Our work was therefore almost entirely in the beds above this horizon.

The grant was handed to Mr. Keeping, who commenced work on May 24 in Parkhurst Forest. The Hamstead series has, it is well known, an extremely limited outcrop. The freshwater beds are succeeded by a brackish series, ultimately passing into marine beds, and occupying successively more and more restricted areas, until on the very apex of Hamstead Hill we find what is evidently the basal bed of a marine series of some importance. Most of the fossils have disappeared by weathering owing to proximity to the surface, but a very distinct and almost gigantic oyster, *O. callifera*, often bored by *Lithodomus*, has withstood the atmospheric action. The formation, being higher than anything in England beneath the Pliocene, has always attracted interest, and the importance of finding other and better outcrops has thus appeared very great. It seemed highly probable, looking at the contour of the land and observing the dip inland at the cliff line, that such would be found in the high ground of Parkhurst Forest. Indeed, that most accurate observer, the late Mr. Godwin-Austen, stated (Mem. Geo. Surv., Isle of Wight, 1856, p. 37) that specimens of the characteristic *Ostrea callifera* had been found on the surface there. Keeping had also found, rather low down, some shelly matter which he took to be the *débris* of marine shells. We accordingly commenced by sinking a pit in the high ground towards the north of the Forest, known as Mark's Corner, choosing a disused gravel pit within fifteen or twenty feet of the summit in order to avoid the labour of digging through the drift. After getting through the base of the gravel and clay to a depth of twelve feet we came to unweathered laminated beds with partings of white sand, containing *Paludina*, the small globose fruits so abundant in the Hamstead series, and remains of freshwater fish. These clearly belong to the freshwater series of Hamstead, and we consider their horizon to be about twenty-five feet below the *Corbula sub-pisum* beds of Forbes. The next essay made was on the Signal Hill, a mile to the South, and also in a gravel pit about twenty feet from the summit. Here we found mottled green clay ten feet thick under five feet of gravel with *Paludina*, *Planorbis*, *Unio*, *Chara*, and a fragment of *Emys*. These also were clearly in the freshwater series and correspond with the mottled bed about fifteen feet below the *Corbula* bed. As these are the highest points of the Forest it thus seems perfectly safe to conclude that no higher beds occur in Parkhurst Forest than at Hamstead, and that the latter presents by far the best development of them.

The escarpment forming Hamstead Cliff is cut through a hill 210 feet high, the crown of which has already disappeared. The highest marine beds are confined to the apex of this hill and cannot have more than a few superficial yards extent, the rapid weathering threatening indeed to remove every vestige of them before many generations shall have

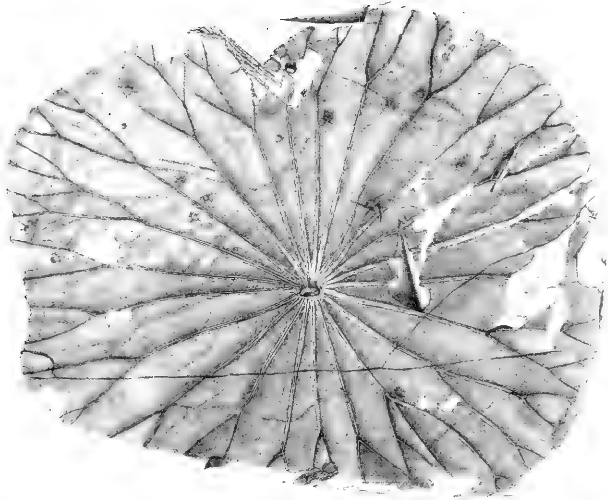
Plate III.



J.S. Gardner lith.

West, Newman & Co. imp.

Illustrating the Report on the Higher Eocene Beds of the Isle of Wight.



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passed away. Opposite the very apex of the hill a huge mud stream descends from a sort of *cirque*, like a glacier, to the sea; a little west a second stream also finds its way to the Solent. The rest of the escarpment, save where local slips have occurred, is overgrown with a dense tangle of vegetation. The mud streams are fed by slips from the terraces overhanging them, and in the terraces the upper Hamstead beds are exposed and can be worked. The lower Hamstead beds can be got at in the low cliffs met with here and there along the shore, while the Bembridge marls are best seen in the rather extensive flats exposed between tides. In proceeding eastward from the mud streams the dip brings lower beds to the surface in succession.

The beds have been described in the Survey Memoirs by Forbes and Bristow, but the death of the former whilst the work was in progress undoubtedly led to its being published in the imperfect state in which it still remains. The marine beds at the summit are, according to these authors, twenty feet thick. The next thirty feet beneath are more or less brackish, and easily distinguished by the presence of *Cerithium*. The thickness of the remainder of the beds, down to a shelly band called the 'white band,' forming the 'middle estuarine and freshwater,' is stated to be fifty feet, but it must evidently exceed 100 feet, for the 'white band' is within about forty feet of the sea level, and the hill, as we have seen, is 210 feet high. About thirty feet down in them, and forming the ledge of the second terrace, is a bed of compact and distinctly laminated clay which may be distinguished as the 'Leaf bed' of the Hamstead series. It is full of a peculiar creeping root, from one half to nearly an inch in diameter, and jointed at intervals of three feet or more by rounded nodes an inch across, from which radiate closely set straight filamentous rootlets, two or three inches in length, and clothed with fibrils. The scars left by the rootlets are small and mammillated, so that when by chance a node has been severed and deprived of rootlets, it has all the appearance of an echinated fruit. The roots are jet black, without netted markings or veins, and contrast strongly in colour with the whitish macerated fragments of sword-shaped leaves which accompany them. This contrast in colour and preservation appears due to the fact that the former were buried in mud even whilst living and never exposed on the surface, whilst the latter had reached the last stage of decay before being silted over. No leaves whatever are found in this bed except *Nelumbium*, and even these are of such extreme rarity that, during about a week's search, only three undeveloped leaves and a part of a developed one were met with. The figure exhibited (plate IV.) is from a nearly perfect specimen in the British Museum. The leaves, so far as outline and venation go, appear to belong unquestionably to *Nelumbium*, and the root-stocks are, according to Heer, of the same plant. They seem, however, from their present appearance, to have been quite hollow, like cane roots, whilst those of *Nelumbium* are so fleshy and succulent that they are cut up into lengths and largely eaten as a vegetable. *Nelumbium* is at present an inhabitant of Asia, the Philippines, and Australia, and formerly grew in the Nile. It has been found fossil in some of the Tertiaries of Central and Southern Europe, and I believe the same species occurs in Antrim.

We are also fortunate in discovering the rare fruit shown in fig. 11 (plate III.). It was apparently a rounded or subangular capsule with thick walls and two or more chambers. The seeds are numerous and compressed

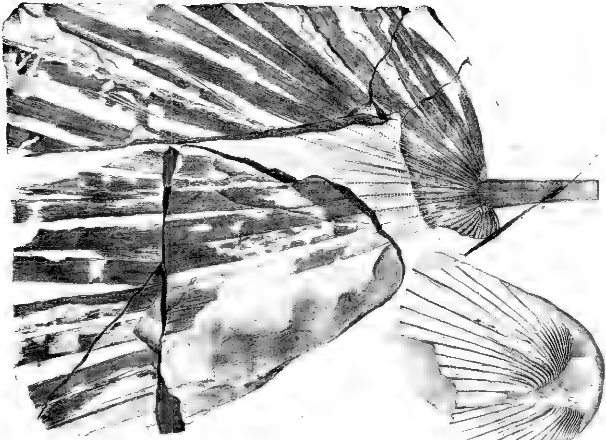
and angular. It greatly resembles the fossil fruit called *Gardenia* by Heer, from Bovey, but I am more inclined to place it under the *Iridaceæ*.

The rest of the Hamstead beds consist either of unfossiliferous mottly clay, or of greeny blue and darker carbonaceous clays with innumerable partings of freshwater shells, such as *Melania*, *Melanopsis*, *Paludina*, *Unio*, *Cyrena*, with enormous quantities of *Cypridæ* and fish scales. But scarcely less numerous than the shell layers are layers of a black, shiny, globose fruit, the size of a currant; and of a small seed, sometimes mingled with the fruits and sometimes in separate layers. The enormous majority of these fruits are merely empty husks, wrinkled and flattened; but occasionally they will be perfectly round, and are seen, if broken whilst quite fresh, to contain two sets, each of three angular cells, base to base, containing one, or perhaps more, ovate, keeled, smooth, inequilateral seeds. Exteriorly, the fruits when full are smooth, quite round, with a slight scar of attachment, and in this condition they may be picked up in numbers, washed out on the shore. The husks were named *Nymphæa Doris* by Heer, on the supposition that they were simple nut-like seeds, though no other remains of *Nymphæa* had been found associated with them either here or at Bovey—and the globular fruits were called *Carpolithes globulus*, Heer, with the suggestion that they might perhaps be the fruit of a palm (Q.J.G.S., 1862, p. 375). The most interesting thing about them is the truly prodigious quantities in which they are scattered throughout a thickness of not much less than 250 feet of sediment. The plant seems to have survived, in undiminished numbers, the innumerable vicissitudes which over and over again changed the quality of the sediment and the assemblages of mollusca living in it. It only disappears when the water had become entirely salt, if not altogether open sea. A proportion of the drifted seeds, which also form continuous layers, appear to have been shed from these fruits, but they are associated with a small furrowed and shortly bearded seed, described as *Cyperites Forbesi*, Heer.

This author has also identified some fragments of a dicotyledonous leaf from near the base of the beds as *Andromeda reticulata*, Ett., and the 'Taxites' of Forbes as *Sequoia Couttsiæ*, Heer, of Bovey. The cones associated with the exceedingly delicate foliage of the latter were, however, compressed and in fragments. If they are of the same species as the perfect specimens obtained from Hordwell, with which they seem to agree in every particular, they would be *Athrotaxis* and not *Sequoia*, the one being an Australian shrubby conifer frequenting river banks, and the other the well-known mammoth tree, or *Wellingtonia*, of the Sierra Nevada in California.

This, except two *Charas* and the *Carpolithes Websteri*, brings our list of Hamstead plants to a close, but the so-called Bembridge marls beneath are in reality part of what is an absolutely continuous formation, deposited under approximately identical conditions. The outcrop of the beds along the shore was described by Forbes in great detail, and he estimated their total thickness at 75 feet, but as no other measurements are given, we must locate our plants rather indefinitely.

Near the top, not far beneath the 'black band,' or dividing line, the fronds of a large fan-palm seem not uncommon. The radius of one measured 2 feet 4 inches, and was even then imperfect; the leaf was pyritised and very thick. The leaf-stalk measured 2 inches across, was smooth, angular at the back, and of such substance that a piece of it was mistaken for a chelonian bone. It is evidently the *Sabal major* of Heer.



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The associated bones of a young crocodile were found by us near the same spot.

About half-way down, as nearly as we could judge, and associated with *Melania turritissima*, we came upon a patch about 30 yards long and 3 or 4 yards wide, almost made up, to a depth of nearly 6 inches, of the detached leaves of a finely cut Myrica. These measure from 2 to 3 inches in length, and from a little over a 16th to a little under a quarter of an inch in breadth. The vast majority are black in colour and rather curled or shrivelled at the edges. A small proportion are larger, brown, and transparent-looking, clearly exhibiting the venation, and are quite flat. I had previously regarded fragments of this plant from the Insect bed of Gurnet Bay as *Gleichenia*, but the more perfect specimens now obtained prove the venation to be that of a dicotyledon. A narrow-leaved reed was massed together not far off in a similar way.

A little above the band of septarian stone in which insect and vegetable remains occur so plentifully farther east, we found a few dicotyledonous leaves, and pinnæ of *Chrysodium lanzœanum*, in dark sandy clay, and some twigs of the conifer which so curiously resembles in its foliage the *Doliostrobus* found at Aix in beds of not very dissimilar age (pl. III., fig. 32). They are perfectly preserved, and have now been found associated with the detached scales of a cone, confirming the correctness of their reference to *Doliostrobus*. At a somewhat corresponding horizon on the Newtown River side, we found the winged seed of the *Engelhardtia*, so abundant in the Insect bed, and other dicotyledonous remains.

The small *pine cone* figured (pl. III., fig. 31) was probably washed out of the same bed. The specimen is now wholly pyrites, excepting a small core of lignite to each scale, and the internal structure is invisible. The scale heads are hexagonal and considerably raised, and the pine appears to have belonged to the same section as *P. Mugho* and its allies. No Tertiary species at all resembling it has been described.

A little lower down, among *Cyrena pulchra*, the small-leaved *Sabal* (pl. V., fig. 1), or other fan-palm occurs, and is distinguished by its long, smooth, and slender foot-stalk.

We see from the foregoing that the number of plants in the Hamstead beds proper is exceedingly restricted, and affords no adequate grounds for their correlation with the Bovey Tracey deposits. The common fossils of Bovey are the common fossils of the black beds of Bournemouth, while the common plants of Hamstead are not found beyond the limits of the Isle of Wight, with the exception of *Carpolithes Websteri*. The flora of that part of the Hamstead series, called the Bembridge marls, is considerably richer, and anyone living on the spot could, doubtless, vastly increase the number of species known, as Mr. A'Court Smith has done from the 'Insect bed,' [1] but neither its prevailing palms, conifers, ferns, nor fruits have been found at Bovey, with the possible exception of *Carpolithes Websteri*. In descending through the Headons the number ot plants continually increases, until in the Bournemouth beds beneath, a truly astounding variety is met with, scarcely, I should think, to be paralleled in any country at the present day. We seem as the plants diminish in

[1] I was able on a recent visit to Gurnet Bay, in company with the Marquis de Saporta, to identify the following additional plants in Mr. Smith's collection: *Cinnamomum lanceolatum*, *C. polymorphum*, *Zizyphus Ungeri*, species of *Rhus*, *Viburnum*, and *Ficus*, and a *Lygodium*.

number to have a diminishing temperature, though the presence of *Sabal major* in the Bembridge marls, and of *Nelumbium* higher up, negatives the idea that the climate had down to that period made any near approach to temperate.

The only one of the fruits met with in great abundance that is perhaps common to Bovey is, as already mentioned, the *Carpolithes*, or *Folliculites Websteri*; but in the first place it is doubtful whether the species is actually the same, and in the second it is characteristic of the Bembridge marls and not of the Hamstead beds proper, and ranges downward into the Lower Headon. It is a small ovate fruit, Plate III., figs. 21–27, slightly curved and more or less flattened on two sides. The integument is deeply furrowed or corrugated, except over the base, which is broad and smooth, with a depressed scar in the centre, around which it is slightly puckered. It dehisces longitudinally, and the thick, leathery, or woody, separated valves are found in layers nearly half an inch deep, forming uninterrupted sheets, which probably have an immense horizontal extent. A few of the unopened fruits contain a smooth hollow cast in pyrites, keeled on one side, slightly recurved, with a small scar, and truncated at one end and pointed at the other (figs. 28, 29). It is more likely that this is a mere infiltrated mould of the interior than that it represents the seed. In the majority of the closed fruits there is nothing but a small white membranous sac (figs. 22, 25, 27) in startling preservation, but in these cases the fruits are compressed and may have been abortive. There is no further evidence to show whether they are cryptogamous,[1] and indeed they cannot yet be assigned positively to any living family or even order—a fact to be regretted the more, as they are widely distributed and have been frequently described. We cannot help being more and more struck with the fact that although resemblances can always be found between living and fossil leaves, so that the several fragments can be fitted with the name of an existing genus, very few Tertiary fruits indeed can be assigned to existing genera, particularly when their structure is well preserved.[2] It thus appears that at Bovey there were no leaves found that presented any difficulty, and the dicotyledonous forms, however fragmentary, were referred to twenty-one species under various existing genera, such as *Quercus*, *Dryandra*, *Eucalyptus*, &c. But the remarkable feature of that flora, in which, as at Hamstead, fruits were unusually numerous, is that not a single fruit or seed belonging to any one of the genera represented by leaves has yet been found. The fruits supposed to be determinable were three species of *Nyssa*, two of *Vitis*, two of *Anona*, one each of *Nymphæa* and *Gardenia*, and there are seven indeterminable ones, called *Carpolithes*. Nothing could place in a stronger light the doubt attaching to the determinations come to in the case of the Bovey Flora.

In addition to the Bembridge marls, *Folliculites* reappears sparingly in company with a deeply interesting fruit in the Lower Headon. There is a band about a foot thick near the top of that formation, both at Hordwell and in the Isle of Wight, which is black with so-called 'seeds,' an inch of the matrix appearing to contain some hundreds of them. It is in reality a minute asymmetric, echinated fruit, appearing to be bearded at both ends, and formed of a large and a small valve (pl. III., fig. 30). When

[1] Described by Sir J. D. Hooker, *Quart. Journ. Geol. Soc.*, vol. xi., p. 566, as Sporangia. See notes to description of plates.

[2] See Bowerbank's *Fossil Fruits of the London Clay*, or Von Mueller's *Vegetable Fossils of the Auriferous Drifts*.

dehiscent, the smaller valve in falling away leaves a pear-shaped or key-hole-like opening (pl. III., figs. 30 and 30b), and the fruit is empty or contains, like *Folliculites*, a membranous sac. The large valve has a single keel and the smaller possesses three elevated ridges. The vast majority have dehisced, but those that are still closed will usually float in water if washed out of the matrix. I am still in ignorance regarding the proper place of the fruit, but nothing has more deeply impressed me than the persistence of this band. In looking from the shore line at Hordwell across to Headon Hill, and realising that the whole interval was probably once carpeted to the depth of a foot with a mass of fruits of a single species, one realises the extraordinary prodigality of Nature, and marvels that even this stupendous provision for perpetuating the species has not sufficed to rescue it from utter extinction.

DESCRIPTION OF THE PLATES.

Plate III.

Carpolithes globulus, Heer.

Figs. 1–9.—This fruit occurs in enormous profusion. The layers are innumerable and often close together, extending through the Hamstead, except the marine beds, as well as the Bembridge marls. The sorting process has been very effectual, for scarcely a seed or any foreign body is found in the husk layers, though globose fruits are sparsely sprinkled among them. The question is whether the wrinkled and flattened bodies, figs. 5, 6, 9, are distinct from the globose fruits, as supposed by Heer, who named them *Nymphæa Doris* and *Carpolithes globulus* respectively, or whether the view that the one is the empty and husk condition of the other is correct. The round body is clearly a fruit composed internally of compartments, figs. 7 and 8, from which I extracted the seed, fig. 10. This certainly cannot have anything to do with Nymphæa, no remains of which have been found of this age in Great Britain. If the flattened bodies are the integuments of seeds they are obviously of seeds which have not germinated, but of which the albumen has disappeared. The very great diversity of size (compare figs. 5 and 9, which are not extremes) is alone almost conclusive against the view that they are seeds, and their incredible abundance is in favour of their being a waste product, *i.e.*, a vegetative organ which had discharged its functions. The proportion of fruits which have missed shedding their seed is such as may be continually observed in nature. The deeply wrinkled appearance of the husks shows that they were not originally flat, and when not flat they are the globose fruit. The variation in size of the one tallies exactly with that of the other (compare figs. 1, 3, 4 of the globose form with figs. 5 and 9). The two are invariably found associated together, and the globose fruits are never found separately, as might be expected if they were distinct, whilst, on the other hand, no other fruits are mingled with them. The case in favour of separation is unsupported by any argument whatever, and I am convinced it would never have occurred to any one working in the field to regard them as aught but two conditions of the same organism. I doubt whether they are really distinct from *Carpolithes ovulum*, Br.

Fig. 1 is a full-sized fruit; the integument is black and shining, dense and moderately thick.

Fig. 2 shows the scar of attachment.

Figs. 3 and 4 represent the smaller sized fruits of the same kind.

Fig. 5 represents the flat view of a husk, and fig. 6 the edge view of same. (In this state they are the *Nymphæa Doris* of Heer.)

Fig. 7 is a broken fruit showing the outer face of three chambers, and fig. 8 shows the inner face of two chambers. The largest fruits had apparently six chambers, whilst the smaller ones had fewer, and perhaps in the smallest there may have been only one.

Fig. 10 represents three views of a seed extracted from a chamber.

Gardenia (?) *Wetzleri*, Heer.

Fig. 11.—This fine fruit had not previously been found in the Isle of Wight tertiaries, but is evidently the same as the two or three groups of seeds found at Bovey, though these were unenclosed in any capsule. The base was unfortunately broken before we realised that the object was other than drifted wood, and for this reason we are doubtful whether the thick stem which appears to be leading up to it was really attached or not. The capsule is rounded, subangular, and indehiscent. On removing one side it was found to be ligneous or leathery, and disclosed two rows of black and shining angulated and closely-fitting seeds. On removing some of these a second layer of seeds was disclosed beneath a thin wall, so that the capsule appears to be two-celled with four rows of seeds.

Figs. 12 to 15 show various views of the seeds unmagnified. I have found no spiral markings on them like those represented as being present on the Bovey seeds.

These capsules are rare, but have been found in many localities on the Continent in lignite and brown coal, associated with plant-remains characteristic of swamp or marsh floras. I think its reference to Gardenia is probably wide of the mark, but have not yet had time to come to any better conclusion regarding it. It is from the Nelumbium bed.

Cyperites Forbesii, Heer.

Fig. 16.—These are small asymmetric seeds, slightly and unequally flattened laterally, keeled on two sides, deeply lined or furrowed, shortly bearded, and with an adherent foot-stalk. They are represented natural size in fig. 16, while fig. 16*a* represents the edge view, and 16*b* the flattened side magnified.

They are enormously abundant in the Nelumbium bed at Hamstead, occurring in sheets or drifted into depressions caused by hollow valves of Unio or other objects settled in the fine mud.

Folliculites Websteri, Brongniart.

This species even eclipses *C. globulus* in abundance, and has been minutely described by Hooker (Q.J.G.S., vol. xi. p. 566), so that we are perfectly acquainted with its structure. It or allied species have also been described by Bronn, Zenker, Brongniart, Ludwig, Unger, and Heer, so that it possesses a wide range and is highly characteristic of European Oligocenes. Notwithstanding this, the greatest diversity of opinion exists as to its true position in the vegetable kingdom. Thus, Heer believed they were *Pine* seeds; though he afterwards, in the Flora of Bovey, compared them to seeds of *Samyda*, a group of tropical shrubs. Ludwig placed them in *Hippophaë*, the sea Buckthorn of our coasts. Brongniart first considered them to be near to *Thalictrum*, a genus of *Ranunculaceæ*, and subsequently agreed with Unger in assigning them to the *Naiadeæ*. Hooker, however, regarded them as the Sporangia of a cryptogam allied to ferns, and in the view that they are cryptogamic Saporta and I are inclined to coincide. The organism is composed of two valves dehiscing longitudinally, and cannot possibly therefore be a seed, but it might have been a one-seeded bivalved dicotyledonous fruit. The valves are in the great majority found detached; but when still united and uninfiltrated they enclose a membranous sac in which, in one instance, Hooker detected some extremely minute transparent granules which he regarded as spores. Less compressed specimens enclose a cast in pyrites of the interior cavity, which cannot, however, represent the seed, as the membranous sac can be seen within it instead of enveloping it. It may be the membrane of a sporular sac, as interpreted by Hooker, or it might be the proper coat of a seed, as the albumen or kernel rapidly disappears in wet, sometimes leaving the membranous coat, as in the case of the cherry stones quoted by Heer in the Flora of Bovey, p. 58. But any determination, to be acceptable, must ally them to some aquatic, or at least water-loving, social plant, for they are met with in prodigious profusion, almost to the exclusion of everything else, wherever beds have been formed in sluggish shallow freshwater during Oligocene times, whilst they are absent where the spoils of woodland floras are deposited.

Figs. 17 and 18 are side views of two specimens, natural size.

Fig 19.—A fruit dehiscing, showing an infiltrated kernel.

Fig. 20.—A single valve, exposing kernel.

Fig. 21. Edge view of a small fruit.

Fig. 22.—A membranous sac removed.

Fig. 23.—Edge view of an infiltrated, and fig. 24 of an uninfiltrated, specimen.
Fig. 25.—An opened fruit exposing the sac.
Fig. 26.—Basal view of an infiltrated, dehiscing fruit.
Fig. 27.—Membranous sac.
Fig. 29.—Edge view, and fig. 28 side view, of infiltrated kernel.

Carpolithes Headonensis, Sp. Nov.

Fig. 30.—Several fruits, natural size. The rest of the figures magnified.
Fig. 30*a*.—Back view showing dorsal keel.
Fig. 30*b*.—Side view, 30*c* back view, of more compressed specimen.
Fig. 30*d*.—Front view of the large valve.
Fig. 30*e*.—Oblique view, showing both valves.
Fig. 30*j*.—Three-quarter view.
Fig. 30*i*.—Exterior, and 30*h* interior, face of small valve.
Fig. 30*g*.—Well-developed fruit showing both valves, and 30*f* a similar fruit after dehiscence, with small valve removed.
From the Lower Headon, Hordwell.

Pinus Vectensis, Sp. Nov.

Fig. 31.—The small pine cone figured was probably washed out of the Bembridge marls, and is unique. It measures 32 millims. in length and 22 in breadth, and is composed of some 40 scales. The scale heads are hexagonal and rather prominent, but partially obscured by encrusting pyrites. No internal structure is visible. It is the smallest pine cone yet recorded from our tertiaries, and appears to be allied to the section of *P. Mugho*. A much larger species is also found in these marls.

Doliostrobus Sternbergi, Goepp.

Figs. 32, 33, and 34 represent some very perfect foliage from near the base of the Bembridge marls, that hitherto recorded having been in the state of casts. The discovery by Mr. A'Court Smith, in June last, of slabs at Gurnet Bay in which the foliage is associated with the detached and characteristic araucaria-like scales described by Saporta and Marion, places the correctness of this determination beyond any doubt.

PLATE IV.

Nelumbium Buchii, Ettingshausen.

Magnificent specimen of *Nelumbium* leaf in the British Museum. The actual margin is preserved over a great portion of the periphery, but seems in places to have been rather heedlessly cut away. The leaf is peltate, nearly circular in outline, notched on the uppermost margin and with radiating venation, the vein proceeding to the base of the notch being stronger than the rest. The principal veins fork, but reunite near the margin, and the secondary venation is obscure. The articulation with the petiole is very visible in the centre of the leaf.

This *Nelumbium* is one of the most interesting of our Eocene plants, as it is not distinguishable from the Sacred Lotus, so celebrated for its associations and for the beauty of its rose-coloured flowers. Leaves are exceedingly rare at Hamstead and are generally represented by torn shreds or immature specimens. Rhizomes, identified by Heer and Saporta as those of *Nelumbia*, abound in the *Nelumbium bed*, but hitherto no trace, either of the remarkable fruit, or of the seeds, has accompanied them.

PLATE V.

Flabellaria Lamanonis (?), Brongn.

Fig. 1.—This palm has a small leaf with a long, slender, perfectly smooth foot-stalk, and must have been a graceful species. It is from the Bembridge marls.

Sabal Major.

Fig. 2.—The base of a leaf from the Bembridge marls. Enormous leaves are sometimes visible, though it is impossible to remove them. Seeds of *Sabal* are common at Sheppey, but have not been met with in these beds.

Report of the Committee, consisting of Mr. W. H. BARLOW, Sir F. J. BRAMWELL, Professor JAMES THOMSON, Sir D. GALTON, Mr. B. BAKER, Professor W. C. UNWIN, Professor A. B. W. KENNEDY, Mr. C. BARLOW, Professor H. S. HELE SHAW, Professor W. C. ROBERTS-AUSTEN, *and* Mr. A. T. ATCHISON (*Secretary*), *appointed for the purpose of obtaining information with reference to the Endurance of Metals under repeated and varying stresses, and the proper working stresses on Railway Bridges and other structures subject to varying loads.*

IN a report to the British Association in 1837, on strength and other properties of cast iron, Mr. Eaton Hodgkinson ('Brit. Assoc. Report for 1837,' Part i. pages 362 and 363) made announcements, from his experimental researches, to the following effect:—That in various experiments on transverse loading of bars he had found visible permanent sets produced by such small loadings as $\frac{1}{30}$, $\frac{1}{52}$, and $\frac{1}{80}$ of the breaking weight; showing, he said, '*that there is no weight, however small, that will not injure the elasticity*;' and as a conclusion that '*the maxim of loading bodies within the elastic limit has no foundation in nature.*'

Again, in the 'Brit. Assoc. Report for 1843,' Part ii. page 24, Mr. Hodgkinson, after detailing further experiments on the same subjects, says:—'It appears from the experiments that the sets produced in bodies are as the squares of the weights applied, and that there is no weight, however small, that will not produce a set and permanent change in a body, and that bodies when bent have the arrangement of their particles altered to the centre; and when bodies, as the axles of railway carriages, are alternately bent, first one way and then the opposite, at every revolution, we may expect that a total change in the arrangement of their particles will ensue.'

Such assertions as those in Mr. Hodgkinson's two communications here referred to, if accepted in full, must necessarily induce very uncomfortable feelings as to endurance of engineering structures. Mr. (now Professor) James Thomson, however, in a paper published in the 'Cambridge and Dublin Mathematical Journal,' vol. iii. p. 252, Nov. 1848, without abandoning the idea of there being some real foundation in nature for prevalent opinions as to limits of elasticity, showed how the elastic range of change of form might, in many of the ordinary cases of materials newly prepared by manufacturing processes, be found to be very narrow on account of the existence of mutual strains or stresses among the particles composing them—that thus permanent sets might be met with on the application of very small loadings—that in this way, through the ductile yielding of the more severely stressed parts, the range of elastic action, or range of action within elastic limits, would be greatly widened, and that after the application of a heavy load, which the material could properly bear, subsequent applications of any smaller loads would produce no new permanent set or alteration—none, at any rate, in any way corresponding to those great and alarming alterations indicated in Mr. Hodgkinson's announcements. (That paper of Professor Thomson's came, besides, under the notice of practical men through its having been re-

published in one or more of the engineering journals of the time; and it has recently been republished in the article on 'Elasticity' by Sir William Thomson in the 'Encyclopædia Britannica.')

In the year 1849 a series of experiments undertaken with the view to ascertain the effect of repeated changes of load on iron structures was carried out by Capt. (now Sir Henry) James, R.E., and Lieut. (now Sir Douglas) Galton, R.E., in conjunction with Professor R. Willis, on behalf of the Commissioners appointed to inquire into the application of Iron to Railway Structures. In the course of these experiments, cast-iron bars, 3 inches square, placed on supports 14 feet apart, were subjected to a succession of blows from a swinging weight; the general result obtained was, that when the blow was powerful enough to bend the bars through one-half of their ultimate deflection (that is to say, the deflection which corresponds to their fracture by dead pressure), no bar was able to withstand 4,000 of such blows in succession; but all the bars (when sound) resisted the effects of 4,000 blows, each bending them through one-third of their ultimate deflection. Other cast-iron bars of the same dimensions were deflected slowly by a revolving cam four times per minute, whilst others, in addition to deflection by the cam, were subjected to violent tremor. The results of these experiments were that when the deflection, repeated in some cases 100,000 times, was equal to one-third the ultimate deflection, the strength of the bars, as shown by subsequently breaking them under a dead load, was not reduced. When, however, the depressions produced were equal to one-half of the ultimate deflection, the bars were actually broken by less than 900 depressions. Experiments were also carried out by slowly drawing a load from end to end of the experimental bars, and by running a truck loaded with various weights over the bars at velocities up to 30 miles per hour, in order to test the effect of the rate of motion on the deflection, with the result that it was found to increase steadily with an increase of speed, until at 30 miles per hour it amounted to more than double the statical deflection. To compare the results of these experiments with the effects produced in actual practice, careful observations were undertaken of the deflections of two railway bridges on the South Eastern Railway during the passage of a locomotive engine at various rates of speed, and with the engine at rest upon the bridge; in these cases the deflection produced by the engine passing at 50 miles per hour was observed to be one-seventh greater than that due to the same load at rest.

The investigations of Professors Willis and Stokes, taken in conjunction with these experiments, show that the great relative increase of deflection arising from velocity was due to the comparatively small size of the experimental bars and great deflections employed, and that the increase would be greater for short bridges than for long ones. Thus the increase of the statical deflection may at the highest speeds amount to one-half for bridges of 20 feet span, while for bridges of 50 feet the increase would not be greater than one-seventh, and would rapidly diminish as the spans become greater.

After the publication of the Report of the Royal Commission on the use of Iron in Railway Structures in 1849, the effect of repeated stresses on iron appears to have received no further attention until 1860–61, when Sir W. Fairbairn carried out his well-known experiments for the Board of Trade on a wrought-iron girder. The girder was 22 feet in length, 16

inches in depth, and was supported upon two piers 20 feet apart in the clear. The top flange consisted of a plate 4 inches × $\frac{1}{2}$ inch and two angle irons 2 inches × 2 inches × $\frac{5}{16}$ inch, giving a sectional area of 4·30 square inches. The bottom flange consisted of a plate 4 inches × $\frac{1}{4}$ inch, and two angle irons 2 inches × 2 inches × $\frac{3}{16}$ inch, giving a sectional area of 2·40 square inches, or 1·775 square inches, when the necessary deduction is made for the rivet holes. The statical breaking strength of the girder does not appear to have been accurately known, but it was estimated at 12 tons in the centre, that of the iron being taken at 22·6 tons per square inch. By the revolution of a crank driven by belting a given load was alternately allowed to rest on the centre of the girder, and was lifted off again a great number of times in succession. The following table shows the number of applications of the different loads, the calculated stresses produced in the bottom flange, and the general results.

TABLE I.—*Fairbairn's Experiments.*

No. of Experiment	Number of Applications	Load on middle of Beam	Deflections in hundredths of an inch	Stress on bottom Flange, calculated from the moment of Inertia of the Section
		Tons		Tons per square inch
1	596,790	2·96	16 to 18	5·608
2	403,210	3·50	21 to 23	6·616
3	5,175 [1]	4·68	35	8·853
4	158	4·68	?	8·853
5	25,742	3·58	22	6·774
6	3,124,100	2·96	17 to 18	5·608
7	313,000 [2]	4·00	20	7·560

These experiments show that the girder was apparently able to bear any number of applications of from 3 tons to $3\frac{1}{2}$ tons at the centre, producing a stress from 5·67 tons to 6·62 tons in the bottom flange, without any signs of failure or of decreasing strength, but that the greater loads caused fracture after a certain number of applications.

In a paper by Sir William Thomson, entitled 'On the Elasticity and Viscosity of Metals,' published in the Proceedings of the Royal Society for May 18, 1865, an account is given of experimental researches instituted by him and conducted in his laboratory in the University of Glasgow, through which some new and previously unsuspected properties in the elasticity of metals were discovered. These cannot be fully described here in detail, but it may be mentioned that the new results, of greatest interest and probably of greatest practical importance, related to temporary and gradually subsiding effects left in wires by previous elastic oscillations. Energy was expended (dissipated) much more in any one torsional oscillation of a wire which had for some time previously been kept actively oscillating, than in a like oscillation either of the same or

[1] The beam broke by tension, the bottom flange failing near the centre; the fracture having been repaired, the experiments were continued.

[2] The bottom flange broke under tension close to the plate riveted over the previous fracture.

of a different but similar wire after having been for some time previously in a state of rest or of less active oscillation.

In the continuation of these experimental researches (after the publication of the paper, it would seem) the effects of the kind of fatigue and rest here referred to manifested themselves very remarkably in the oscillation of wires kept almost constantly in activity during most days of the week, but getting rest usually from Friday evening till Monday morning. The successive oscillations diminished in their amplitude, by internal resistance or some condition like viscosity in their elasticity, much less on the Monday mornings, after their Sunday rest, than at other times, succeeding closely to previous activity.

The experiments in connection with the subject carried out by A. Wöhler at Berlin, the results of which were published in 1870, are of great importance. (See 'Engineering,' 1871.)

These experiments proved that, in the case of wrought-iron and steel of various qualities, rupture of the material took place after a certain number of applications of a stress less than the statical breaking stress; that when the stress was alternately tensile and compressive, the range of stress required to produce rupture, treating tension and compression as of opposite sign, was but little greater than the maximum stress applied a similar number of times in one direction only—*i.e.*, simply tensile or simply compressive. And again, when the stress varied from a certain maximum compression to a certain minimum compression, or from a certain maximum tension to a certain minimum tension, the range of stress producing rupture after a similar number of applications differed but little from that in the case where the stresses were in opposite directions.

The following table—No. II.—gives the result of test-bars cut from a steel axle and subjected to torsion. The bars, numbered from 1 to 5, were twisted in one direction only; those numbered from 6 to 9 were twisted in opposite directions alternately, the range of stress being therefore double the maximum stress.

TABLE II.—*Result of Test Bars cut from a steel axle and subjected to Torsion.*

Number of Test Bar	Greatest Stress in Fibres in lbs. per square inch	Number of applications of Stress before Fracture
1	51,360	198,600
2	48,150	373,800
3	44,940	334,750
4	42,800	879,700
5	40,660	23,850,000 [1]
6	29,966	187,500
7	27,820	1,007,550
8	25,680	859,700
9	23,540	19,100,000 [1]

[1] Not broken by this number of applications.

TABLE III.—*Showing the Results of subjecting Bars to Repeated Variations of Tensile Stress.*

Stress applied in lbs. per square inch		Range of Stress = difference between Maximum and Minimum in lbs. per square inch	Number of applications of Stress before Fracture
Maximum	Minimum		
Bars cut from an Iron Axle.			
51,360	0	51,360	800
47,080	0	47,080	106,910
42,800	0	42,800	340,853
38,520	0	38,520	480,852
34,240	0	34,240	10,141,645
47,080	21,400	25,680	2,373,424
47,080	25,680	21,400	Not broken by 4,000,000
Bars cut from a Steel Axle.			
85,600	0	85,600	18,741
74,900	0	74,900	46,286
64,200	0	64,200	170,170
58,580	0	58,580	123,770
53,500	0	53,500	473,766
51,360	0	51,360	13,600,000 [1]
49,220	0	49,220	13,200,000 [1]
85,600	53,500	32,100	1,801,000 [1]
85,600	42,800	42,800	12,100,000 [1]
85,600	37,450	48,150	12,000,000 [1]

TABLE IV.—*Showing the Results of subjecting Bars to Repeated Variations of Transverse Strain.*

(Bars made of spring steel manufactured by Krupp.)

Stress applied in lbs. per square inch		Range of Stress = difference between Maximum and Minimum in lbs. per square inch	Number of applications of Stress before Fracture
Maximum Stress in Fibres	Minimum Stress in Fibres		
128,400	32,100	96,300	22,900
128,400	42,800	85,600	35,600
128,400	53,500	74,900	86,000
128,400	64,200	64,200	191,100
128,400	74,900	53,500	50,100
128,400	74,900	53,500	251,400
128,400	85,600	42,800	35,600,000 [2]
128,400	96,300	32,100	33,478,700
107,000	17,762	89,238	62,000
107,000	35,631	71,369	149,800
107,000	53,500	53,500	400,050
107,000	62,381	44,619	376,700
107,000	70,620	36,380	19,673,300 [2]

In the case of the iron bar it will be noticed that the specimen was able to bear 10,141,645 applications of a tensile stress of 34,240 lbs. before

[1] Unbroken. [2] Not broken by this number of applications of the load.

fracture, but that a similar bar broke with only 480,852 applications of 38,520 lbs., being an addition of $12\frac{1}{2}$ per cent. to the stress; similarly the steel bar withstood 13,600,000 applications of 51,360 lbs. without fracture, while a similar bar broke with 473,766 applications of 53,500 lbs., being an addition of 4 per cent. to the stress.

The preceding table—No. IV.—shows the effects of subjecting test-bars of iron and steel to tensile stresses where the load is completely taken off between each application as compared with the cases where the load varies from a certain minimum to a certain maximum at each application. Thus with a load of 47,080 lbs. per square inch, taken off completely between each application, the iron bar broke with 106,910 applications; but with the same load as a maximum, reduced to 21,400 lbs. as a minimum between each application, the bar failed only with 2,373,424 applications; and it withstood 4,000,000 applications when the minimum load was further raised to 25,680 lbs.

General Deductions of Herr Wöhler.

Material	Maximum Stress on Fibres in lbs. per square inch	Minimum Stress on Fibres in lbs. per square inch
	Bars subjected to tensional or transverse stress.	
Iron	+17,120	−17,120
"	+35,310	0
"	+47,080	+25,680
Cast steel for axles	+29,960	−29,960
" "	+51,360	0
" "	+85,600	+37,450
Untempered cast steel for springs	+53,500	0
" "	+74,900	+26,750
" "	+85,600	+42,800
" "	+96,300	+64,200
	Bars subjected to shearing stress.	
Cast steel for axles	+23,540	+23,540
" "	+40,660	0

In 1881 and succeeding years, Professor Bauschinger, of Munich, published the results of his experiments on the behaviour of metals when subjected to stresses exceeding their elastic limit.[1]

The most important of these is a paper, 'Ueber die Veränderung der Elasticitätsgrenze,' in the Mitth. des k. techn. Laboratorium in München. An abstract of some of these results, and a comparison of them with the corresponding results of Wöhler, is given in a paper by Prof. Unwin in the 'Engineer' for Dec. 10, 1886, and Jan. 7, 1887.

First of all, to show the effect of stretching a bar just beyond its yielding point on the position of the elastic limit. The following table is taken from an earlier paper of Bauschinger's, 1881. It will be seen that if the loading of a bar is repeated, immediately after straining it to the yielding point, the elastic limit is lowered. If a period of rest is allowed, the elastic after-effect comes into play and the elastic limit rises, sometimes above the load previously imposed.

[1] See the *Engineer*, Jan. 7, 1887.

TABLE V.—*Wrought Iron subjected to Tension.*

(Tons per Square Inch.)

Treatment	Elastic Limit	Greatest Load imposed	Remarks
Round bar, 1in. diameter—			
Original condition	9·3	14·5	Yielding
Immediately after	6·55	18·5	"
" "	6·70	22·0	"
" "	7·10	—	—
Round bar, 1in. diameter—			
Original condition	10·5	14·5	Yielding
80 hours after	14·7	18·7	"
68 " "	16·3	21·8	"
64 " "	20·0	22·8	—

The next table relates also to bars strained by tension only, but it indicates the effect of more varied treatment of the bar. It will be seen, in the case of the first bar, that loading again immediately after stretching to the yielding point, the elastic limit is lowered from 11·6 to 8·05 tons. In the case of the second bar, similarly strained but with a period of rest of 69 hours allowed, the elastic limit is raised from 12 to 20 tons. But on reloading immediately the elastic limit is lowered to 4·05 tons. With a three years' period of rest it is raised to 33 tons, just the load with which it had previously been strained. But this artificially produced elastic limit is so unstable that on hammering the bar on the end and reloading it has fallen to 12·5 tons.

TABLE VI.—*Bauschinger's Experiments on the Change of Position of the Elastic Limit.*

(Bar subjected to Tensions only. Tons per Square Inch.)

Treatment	Elastic Limit	Yielding Stress or Breaking-down point	Greatest Stress imposed on Bar
Bar of Bessemer Steel. No. 939c.—			
1. Original condition	11·6	17·4	22·6
2. 1 day after	—	24·8	26·8
3. Immediately after (2)	8·05	27·0	28·3
4. Immediately after (3)	—	28·3	29·6
5. 1 day after (4). [Broke with 34 tons] . .	—	32·4	34·0
Bar 939b. Same Steel—			
1. Original condition	12·0	18·6	21·3
2. 69 hours after (1).	20·0	24·0	26·6
3. ½ hour after (2). Straightened in the lathe .	4·05	25·6	32·3
4. 68 hours after (3)	6·9	33·0	33·0
5. 3 years after (4)	33·0	33·0	33·0
6. 2 days after, and after being vibrated by hammering on end	12·5	32·0	32·0
7. After 2 years, and after heating to cherry red and cooling in water. [Broke at 35·8 tons.]	0	24·6	25·2

TABLE VII.—*Bar subjected to Alternating Tension and Compression.*
(Tons per Square Inch.)

Time between the Loadings	Elastic Limit		Load imposed	
	Tension	Com-pression	Tension	Com-pression
Wrought-iron bar—				
1. Original condition	—	—	13·7	—
2. 6 days	13·7	—	14·5	—
3. 1 hour	—	4·8	—	14·5
4. 5 minutes	—	9·65	—	14·5
5. 20 hours	—	12·9	—	14·5
6. 1 hour	—	—	14·5	—
7. 46 minutes	—	—	—	14·5
8. 30½ hours	—	—	—	6·45
9. 15½ "	—	—	6·45	—
10. 2 "	4·8	—	7·25	—
11. 9 minutes	—	—	7·25	—
12. 27 hours	—	—	—	17·3
13. 30 minutes	—	12·7	—	17·5
14. 3 days	—	—	17·5	—
15. 2 "	—	4·8	—	6·35
16. 2 "	—	—	6·35	—
17. 5 hours	—	7·15	—	7·15
18. Next day	6·35	—	7·15	—
19. 2 days	—	—	—	7·15
20. 2½ hours	7·15	—	7·95	—
21. 4½ "	—	7·95	—	8·75
22. 1 day	8·75	—	8·75	—
23. 9 hours	—	7·95	—	9·55
Bessemer Steel Bar—				
1. Original condition	17·7	—	24·0	—
2. 23 hours	—	3·24	—	24·3
3. 5 "	16	—	24·0	—
4. 4 days	—	4·85	—	8·5
5. 2 "	5·55	—	8·5	—
6. 5½ hours	—	8·85	—	9·7
7. 21½ "	8·85	—	9·7	—
8. 2 days	—	—	—	9·7
9. 4 hours	10·5	—	11·3	—
10. 2¼ "	—	9·65	—	11·3
11. 16 "	9·65	—	11·3	—
12. 23 "	—	9·65	—	11·3

TABLE VIII.—*Bauschinger's Endurance Tests.*

(Stresses in Tension varying from 0 to an upper limit.)

Material	Elastic Limit in tons per square inch		Endurance Test		Tensile Strength in tons per square inch	
	Original	Acquired during repetition of loads	Load applied	No. of repetitions before fracture in millions	Original	After breaking by repetition of loads
Wrought-iron plate	6·84	12·3	7·1	5·17	25·2	23·6
	6·84	13·2	9·85	5·19	25·2	24·3
	6·84	14·4	13·1	5·18	25·2	24·5
	6·84	16·4	16·4	2·28	25·2	
Mild steel plate .	15·6	19·4	16·0	6·68	28·5	
	15·6	18·0	16·0	3·55	28·5	
	15·6	20·0	16·0	11·03	28·5 [1]	
	15·6	16·4	16·0	7·35	28·5	
	15·6	—	19·7	0·67	28·5	
	15·6	19·1	19·7	1·01	28·5	
	15·6	19·0	23·0	0·32	28·5	
	15·6	19·0	23·0	0·76	28·5	
	15·6	19·9	23·0	0·16	28·5	
	15·6	16·4	23·0	0·44	28·5	
	15·6	15·3	23·0	0·62	28·5	
	15·6	20·0	26·2	0·34	28·5	
	15·6	16·9	26·2	0·49	28·5	
	15·6	17·9	26·2	0·07	28·5	
	15·6	12·3	26·2	0·11	28·5	
	15·6	11·5	26·2	0·04	28·5	
Bar iron . .	11·8	21·4	13·2	9·11	26·6	28·2
	11·8	10·7	16·4	7·40	26·6 [2]	
	11·8	10·8	19·7	0·64	26·6	
	11·8	10·6	19·7	0·24	26·6	
	11·8	10·9	19·7	0·84	26·6	
	14·8	16·3	13·8	16·48	26·7	27·1
	14·8	18·6	17·2	9·31	26·7	26·6
	14·8	11·9	19·7	0·67	26·7	
Thomas steel axle	17·6	20·4	16·3	9·58	40·1 [3]	
	17·6	—	26·2	0·62	40·1	
	17 6	20·8	19·7	9·04	40·1	41·0
	17·6	—	26·2	0·22	40·1	
	17·6	—	26·2	0·06	40·1	
Thomas steel rail .	19·0	24·0	16·4	10·19	39·0	39·4
	19·0	17·6	19·7	7·91	39·0	37·7
	19·0	—	26·2	0·57	39·0	
	19·0	—	26·2	0·56	39·0	
Mild steel boiler plate	17·6	18·0	18·4	4·85	26·6	
	17·6	—	21·0	0·40	26·6	
	17·6	—	21·0	0·49	26·6	
	17·6	—	21·0	0·88	26·6	
	17·6	18·4	16·4	6·34	26·6	
	17·6	—	18·7	0·40	26·6	
	17·6	18·0	16·4	6·54	26·6 [3]	
	17·6	16·0	18·7	4·87	26·6 [3]	

[1] Not yet broken in endurance test.
[2] Elastic limit rose to 16·7 and then fell near the end of the endurance test.
[3] Not yet broken.

The Table VIII. contains a summary of all Bauschinger's experiments on the endurance of a bar subject to repeated stresses. He constructed a machine of the same kind as Wöhler's, in which a bar could be subjected to stresses ranging from 0 to an upper fixed limit in tension. He ascertained both the initial elastic limit and the elastic limit acquired under repetition of stress; the initial breaking strength and the strength after the bar had been broken in the Wöhler machine. It will be seen that the elastic limit rises with repetition of stress to a point which is in many cases a little above the load applied. When that is the case the bar suffers a large number of repetitions of load before fracture. If the elastic limit—observed in about a 5 in. length of bar—is very near or below the load applied, the bar breaks with comparatively few repetitions of load.

Now it has been shown that a parabola, known as Gerber's parabola, can be drawn, so as to fit Wöhler's results extremely well. Let the lower stress limit on a bar be denoted p, and let s be the range of stress to which it is subjected, and f its statical breaking strength. Then Gerber's equation is—

$$(p + \tfrac{1}{2} s)^2 + k s = f^2.$$

Bauschinger's results enable us to determine the constants in this equation, and Bauschinger has in fact determined the constants for each of the materials on which he experimented. Using these constants, we can determine the range of stress a bar will bear indefinitely repeated for other conditions of loading. The Table IX. below has been thus computed, and it agrees singularly well with the corresponding results obtained by Wöhler. It is extremely valuable, because Wöhler only determined values of the limiting stresses for three materials, two of them steels of rather high tenacity. Bauschinger's results extend Wöhler's to materials in more common use.

For comparison the corresponding results deduced from Wöhler's experiments are appended in the following table (Table X.). It will be understood that these stresses are the stresses which would ultimately break a bar, with a sufficiently large number of repetitions of loading.

TABLE IX.—*Bauschinger's Endurance Tests.*

(Tons per Square Inch. Stresses requiring 5 to 10 Million Repetitions to cause Fracture.)

Material	Opposite Stresses		One Stress Zero		Similar Stresses		Range Zero, ultimate statical strength
	Least	Greatest	Least	Greatest	Least	Greatest	
Wrought-iron plate .	− 7·15	+ 7·15	0	13·10	11·04	19·02	22·08
Bar iron . . .	− 7·85	+ 7·85	0	14·04	13·03	22·02	26·06
Bar iron . . .	− 8·65	+ 8·65	0	15·75	13·02	21·92	26·04
Bessemer mild steel plate	− 8·55	+ 8·55	0	15·70	14·03	23·08	28·06
Steel axle . .	−10·05	+10·05	0	19·70	20·00	32·01	40·00
Steel rail . . .	− 9·07	+ 9·07	0	18·04	19·05	30·85	39·00
Mild steel boiler plate	− 8·65	+ 8·65	0	15·08	13·03	22·55	26·06

TABLE X.—*Limits of Stress from Wöhler's Endurance Tests.*

(Stresses in Tons per Square Inch for which Fracture occurs only after an indefinitely large Number of Repetitions.)

Material	Opposite Stresses		One Stress Zero		Similar Stresses		Range Zero, ultimate statical strength
	Least	Greatest	Least	Greatest	Least	Greatest	
Wrought-iron . .	− 8·06	+ 8·06	0	15·25	12·00	20·05	22·08
Krupp's axle steel .	−14·05	+14·05	0	26·05	17·05	37·75	52·00
Untempered spring steel	−13·38	+13·38	0	25·05	12·05	34·75	57·05

For many years the only experimental work of importance being carried on in connection with the endurance of metals was that already referred to as inaugurated by Wöhler and continued by Spangenberg and Bauschinger; but in this country, since the commencement of the Forth Bridge works, Mr. Benjamin Baker has been carrying on a series of experiments with the special view of testing the effects of so-called 'fatigue' on the steel used in the bridge as compared with hard steel and with iron.

The experiments may be classified under four heads: (1) Spindles rotating with a weight at the free end, causing alternate tension and compression on the fibres as the spindle revolves. (2) Flat bars bent in some cases one way only, and in other cases both ways. (3) Specimens so designed as to give alternate direct tension and compression on small pieces of metal; and (4) Full-sized riveted girders.

SERIES NO. 1.

	No. of Revolutions	Stress per square inch	Factor a	Factor b
		Soft Steel.		
1	40,510	36,000	1·75	2·45
2	60,200	36,000	,,	,,
3	68,400	34,000	1·84	2·56
4	92,070	,,	,,	,,
5	107,415	,,	,,	,,
6	128,650	,,	,,	,,
7	155,295	,,	,,	,,
8	14,876,432	26,000	2·42	3·4
		Hard Steel.		
9	5,760	67,000	1·88	2·82
10	7,560	65,000	1·93	2·90
11	14,600	53,500	2·36	3·45
12	16,300	,,	,,	,,
13	26,100	46,500	2·72	4·10
14	32,445	51,000	2·40	3·60
15	157,815	40,500	3·03	4·55
16	472,500	34,000	3·70	5·55

SERIES NO. 1—*continued.*

	No. of Revolutions	Stress per square inch	Factor a	Factor b
		Best Bar Iron.		
17	108,160	34,000	1·70	2·38
18	110,000	35,000	1·66	2·32
19	141,750	34,000	1·70	2·38
20	389,050	32,000	1·90	2·65
21	408,000	30,200	2·00	2·80
22	421,470	32,000	1·90	2·67
23	480,810	31,000	1·95	2·75

'Factor a' is the ratio of the ultimate tensile strength per square inch of the specimen to the calculated stress upon the outside fibres, due to the load on the end of the projecting bar. 'Factor b' is the ratio of the static load required to bend the bar a moderate amount beyond the elastic limit, to the load actually imposed upon the revolving bar. These definitions will be made more clear in further references to the table.

The above series includes a representative number of the experiments with rotating spindles. As a rule, the spindles were 1 inch diameter, and projected about 10 inches from the end of the revolving shaft in which they were fixed. A speed of between fifty and sixty revolutions per minute was maintained day and night. The 'soft steel' was fine rivet steel, having a tensile strength of from 60,000 lbs. to 64,000 lbs. per square inch, and an elongation of 28 per cent. in 8 inches. The 'hard steel' was a high-class 'drift' steel, having a tensile strength double the above, and an elongation of one half the extent. The 'iron' was the best rivet iron, having a tensile strength of from 58,000 lbs. to 61,000 lbs., and an elongation of 20 per cent.

SERIES NO. 2.

	No. of Bends	Stress per square inch	Factor a
		Soft Steel.	
24	12,240	44,000	1·59
25	12,325	,,	,,
26	12,410	,,	,,
27	18,100	42,000	1·67
28	18,140	,,	,,
29	72,420	36,000	1·94
30	147,390	34,500	2·03
31	262,680	34,000	2·05
32	1,183,200	27,500	2·55
33	3,145,020	34,500	2·03
		Best Bar Iron.	
34	184,875	34,000	1·68
35	250,513	,,	,,
36	3,145,020	,,	,,

The above series is a selection from the experiments with flat bars

bent laterally. Generally the bars were 1 inch wide by $\frac{1}{2}$ inch thick, and 32 inches long between the bearings. The steel specimens were cut from the tension member plates of the Forth Bridge, and had a tensile strength of about 70,000 lbs. per square inch, and an elongation of 20 per cent. in 8 inches. The iron specimens were rolled bars.

The different effects produced on different materials by the frequent repetition of stress is well shown by those experiments—thus comparing Nos. 8 and 14 in Series No. 1, the stress applied being in each case about 40 per cent. of the ultimate strength, the hard steel failed with only 32,445 revolutions, while the soft steel withstood 14,876,432. Again, comparing experiments Nos. 16 and 23, it will be seen that with about the same number of revolutions the hard steel, though of more than double the tensile strength of the iron, broke under a repeated stress only 10 per cent. greater, thus demonstrating that the ultimate tensile strength of a metal as observed in a testing-machine is no adequate measure of its value as a material of construction.

Other points of interest may be referred to in connection with Series 2. In general the bars were tested in pairs, so that when one bar broke, its companion could be otherwise tested and examined. For example, the companion to No. 28, after being subject to 18,140 bendings, was tested for tension, and failed with 48,000 lbs. per square inch, and 2·6 per cent. elongation; the original strength of the steel being 70,000 lbs. and 20 per cent. elongation. Again, the companion to No. 32 was, on close examination, found to have a flaw like those found in crank-shafts. Nos. 33 and 36 were companion bars bent one way only, so that the stresses were not alternating, hence the largely increased endurance. They were both taken out before actual fracture, but with deep-set flaws, clearly illustrating that the cause of failure under repeated stresses is very frequently not so much a gradual deterioration or crystallisation of the metal, as the establishment of small but growing flaws.

Another noteworthy fact illustrated by these experiments was, that a structure or piece of mechanism may be subject to a repeated stress equal to 90 per cent. of that which would break it, and yet specimens cut from the metal may exhibit no signs whatever of deterioration. The broken half of nearly every specimen in Series No. 2 was tested with that result. Thus, as the stress was applied at the centre of the bars, it followed that at a point distant 90 per cent. of the half-span from the bearings, the stress would be 90 per cent. of that which broke the bar. Although the bars broke short off at the centre, at the point referred to they could invariably be bent double without fracture. Having reference to this fact, and to the fact that the tensile strength was also little affected, Mr. Baker considered that it was hopeless to expect to learn much from testing specimens of metal from structures or machines which have been long in use, unless the experimenter happens to hit off the right moment immediately preceding the commencement of failure.

In order to ascertain whether alternating stresses were as prejudicial to members, such as piston-rods, subject to direct pull and thrust, as to shafts subject to transverse bending, a series of experiments (No. 3) was carried out on specimens so designed as to give alternate direct tension and compression on small pieces of metal. These specimens were of three types, illustrated (not to scale) by figs. 1, 2, and 3. In the first, the pieces of metal tested were sometimes of round and sometimes of flat cross-section, and were bolted to a couple of spring bars, as shown on the

sketch; the stress being applied by opening and closing the legs of the tongs, and thus putting the metal into alternate tension and compression. In the second group, the spring bars and specimens were all sawn and

FIG. 1.

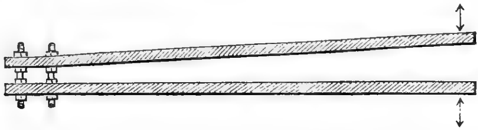


FIG. 2.

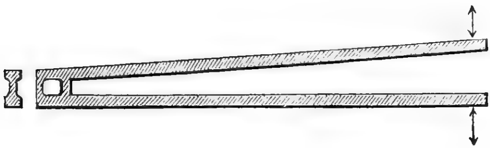
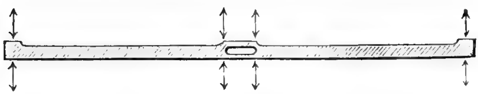


FIG. 3.



slotted out of one piece of steel, and the necessity of constantly tightening up the nuts was thus avoided. In the third, the specimens were shaped as shown by fig. 3, and a bending stress was applied at the centre of the bars.

SERIES NO. 3.

Soft Steel.

Fig.	No. of Bends	Stress per square inch	Factor a
1	28,008	37,000	1·90
	49,320	38,000	1·84
2	11,880	28,000	2·50
	29,568 (hard steel)	16,000	4·90
3	230,513	35,000	2·00
	294,735	25,000	2·80

SERIES NO. 4.

The opportunity afforded by the large use of special plant and machinery at the Forth Bridge Works has been taken advantage of to note the influence of varying stresses on full-sized riveted steel girders. These observations are still in progress, and can be but very briefly referred to herein. In one instance the lever of a large plate-bending press is of box-girder section, built up of eight $4'' \times 4'' \times \frac{5}{8}''$ angle bars, two $13'' \times \frac{3}{4}''$ web plates, and two $17'' \times \frac{1}{2}''$ flanges. The span is 15 feet 8 inches, and the ordinary daily working stress on the metal is 43,000 lbs., and occasionally 57,000 lbs. per square inch, the breaking strength being 70,000 lbs. Many thousand applications of this stress have been made, and

the beam has taken a permanent set of $\frac{7}{8}''$, but so far is otherwise intact. Observations are also being made of the behaviour of sixty riveted steel box-girders of 18 feet span, built up of two $12'' \times 3''$ channels and two flange plates; which girders are subject to very many thousand repetitions of stress ranging from zero to 29,000 lbs. per square inch.

The Committee, having carefully considered all the evidence procurable up to the present time, have arrived at the following conclusions:—

(1) For those cases in which the dead weight is much less than the live load, it is the practice of engineers to adopt a lower working stress than five tons per square inch, as permitted by the Board of Trade.

(2) In those cases where the dead weight is large compared with the live load, the results of experiments on the fatigue of metals indicate that a higher working stress is permissible with the same degree of safety as with the lower stresses in smaller structures. In small bridges, where the effect of wind pressure is practically insignificant, the maximum stress, being due to the passage of the live load, is of frequent recurrence; while in large structures, where the wind pressure is a very important element in arriving at the maximum stress, it is clear from the infrequency of heavy wind pressures that the maximum stress but rarely recurs, and that thus

(3) If the working stress permissible be arrived at from the consideration of the experiments upon the endurance of metals under repeated changes of load, then the proper rolling load to assume is certainly that which may be reasonably expected to come upon the bridge a great number of times.

(4) With regard to dynamic action, the shocks resulting from bad rail-joints are of importance. Rails in 60-feet lengths are occasionally used over bridges in order to avoid injurious effects from this cause.

The Committee offer the following recommendations:—

(*a*) That in the case of very small girders and cross-girders, when the forces operating upon them are either all tensile or all compressive, the maximum stress to which wrought iron should be subjected by the quiescent weight of the moving load, added to the weight of the structure, ought not to exceed 4 tons per square inch.

(*b*) That in the case of bridges or structures of such magnitude that the dead weight is more than twice that of the moving load, the stress upon wrought-iron may be safely increased to nearly 6 tons per square inch.

(*c*) That in those members or parts of structures which are exposed to stresses alternating from tension to compression, the maximum tensile stress added to the maximum compressive stress should not exceed 6 tons per square inch, nor the maximum tensile stress or compressive stress considered independently exceed 4 tons per square inch.

(*d*) In computing the strength required to resist wind pressure, considering that very high pressures are of rare occurrence, the stress upon wrought iron from the effects of wind may safely be taken at 6 tons per square inch; that

(*e*) In steel of suitable quality a stress 30 per cent. greater may be allowed.

Report of the Committee, consisting of Mr. F. GALTON, General PITT-RIVERS, Professor FLOWER, Professor A. MACALISTER, Mr. F. W. RUDLER, Mr. R. STUART POOLE *and* Mr. BLOXAM (*Secretary*), *appointed for the purpose of procuring, with the help of* Mr. FLINDERS PETRIE, *Racial Photographs from the Ancient Egyptian Pictures and Sculptures.* (*Drawn up by* Mr. PETRIE.)

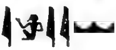
THE Committee charged with the administration of the grant voted at the last meeting of the Association for the purposes of obtaining racial photographs from the Egyptian monuments, after consulting on the most effective means for the purpose, and considering the list of subjects and the practical details of the matter, placed the carrying out of the object in my hands, on the understanding that I should follow the lines agreed on, so far as circumstances permitted. Since my return to England, and submitting a preliminary report to the Committee, they have requested me to prepare an account of the work which should serve as their own report to the present meeting.

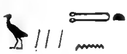
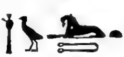
After receiving a first list from Dr. Poole, and a long and full statement of *desiderata* from Rev. H. G. Tomkins, the list of subjects was decided on; and these have been reproduced, unless prevented by the condition of the monuments. Besides these a great number of other subjects have been taken, in course of a full search at Thebes for all racial figures. The first idea was only to obtain photographs; before starting, however, the Committee fully agreed on the importance of taking casts of the sculpture where photography would be difficult. And in actual work I never took a photograph if it were possible to take a paper cast; the larger scale and better representation of a cast, and the facility with which a photograph can be taken from it afterwards, under the best circumstances, instead of on a high wall or in a bad light, rendered this way far the most satisfactory. The results are that, instead of a collection of photographs only, there will be finally (1) a series of about 150 casts, comprising 268 heads, which will be presented to the British Museum; (2) other selected sets of casts from the paper moulds, which can be obtained for museums on application to me; (3) a series of forty photograph negatives of paintings, and a series of photographs from all the casts, excluding duplicates; (4) prints of all these plates, which can be ordered from Mr. Browning Hogg, 75 High Street, Bromley, Kent, at cost price; the charge for printing is 2*s.* 3*d.* per dozen if selected from a loose set; or 45*s.* for the whole, mounted on printed sheets in a case.

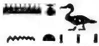
The following is the list of casts and photographs so far as they can be yet named with certainty; the names of the people represented are, however, often not given, and still oftener destroyed; but yet the race may be determined by comparison with other sculptures which show the same dress or characteristics, and also by the general subject of a whole scene, after the detailed names have been lost.

Some subjects which were proposed have not been done, owing to the injury or destruction of the sculptures, and particularly to the bad state and dirt of the paintings, which made photography often impossible. On the other hand, many of these casts are from subjects not named in the original request.

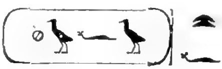
CASTS.

	Hieroglyphic name	Transliteration	Modern name	Number of cast
Karnak—				
Horemheb, pylon		Hanebu, woman	Greek	1
	?	?	Unknown	2–4
		Pun, princes	South Red Sea	5–8
Top E. end with square shields		?	?	9
Beneath horses in attack on 9		?	?	10
Great hall, S. side, high E.		Derdeni	Dardanians	11–12
		Khita	Hittites	13–15
high, mid.	?	?	Among Rutennu	16, 17
mid. of mid.		Lza	Kalb Luzeh, N. Syria	18–20
mid. top		Ai	Kefr. Aya, N. Syria	21–23
E. low, slain	?	?	?	24, 25
	Fort near Lza on Orontes	?	?	26, 27
fort E. of Sheshank		Aujsel	Aujel, W. Aleppo	28
E. low, slain.	?	?	Near Ataka[r], N. Syria	29
Cross wall		Askalna	Askalon (two women)	30–33
	?	?	Unknown	34–35
Triumph of Sheshank		Haniniau	Beit Hanina	36
		Ganaata	Wady Ganāta	37
		Iudeh malek	Royal place in Judea	38
		Adir ////	Et Tireh	39
Great hall, N. side		Shasu	Bedawin	40–48
		Khita	Hittites	49–58
		Khal, chiefs	Khalus (Koweik)	59–61
		Amar	Amorites	62–65

Karnak—continued.	Hieroglyphic name	Transliteration	Modern name	Number of cast
		Tahennu	By Syrtes	66–68
		Ruthennu	N. Syria	69–70
	?	Tahennu ?	?	71, 72
	?	Ruthennu	N. Syria	73–75
in chariot		Khita	Hittites	76, 77
		Innuaa	Einya ?	78–81
	?	Tahennu ?	?	82–85
		Amar	Amorite (full face)	86
		Arm	Orma	87
Great hall, E. end		Rmennu	Lebanon	88–93
	 of 	Shasu of Kanana	Arabs, Hurbet Kana'n	94
Nekhthorheb, gate		Menti of Sati	Bedawin of Sinai	95
		Tahennu	By Syrtes	96
Thothmes III. Pylon N. face, W. half 3rd line . 2		Annena	Annine (Greek)	97
3		Tebana	Debeni	98
4		Antebeth	?	99
7		U /// then	?	100
9		Nehetum	?	101
10		Shatitum	Settite	102
11		Thathabu	?	103
12		Ulethet	Wenthet	104

Karnak—continued.	Hieroglyphic name	Transliteration	Modern name	Number of cast
14		Memthu	Metta	105
4th line. 2		Anhimeru	Emmamret	106
3		Ahuul	Avalitis (Greek)	107
5th line. 4		Abes	Abso	108
5		Habnu	Heban	109
6		Asteses	?	110
7		Aar	Ara	111
		Thenas	?	112
6th line, W.	Name lost	?	?	112A
mid		Utn.	Udeïn	113
		Mentu	Mundu	114
6th line		U ///////	?	115
S. face, E. half, top		Adal	Adal	116
S. face, W. half, mid.		Dmesku	Damascus	117
S. face, W. half, low		Teshfu	Tashfay	118
Pylon by sanctuary, heads all alike, two typical ones				119–20
Ramesseum—				
Pylon W. face, N. half. line B, 7, 8, 9		Marma	Merom	121–23
line C, 1		Amaur-dapur	Amorite of Tabor	124
line C, 4, 5, 6		Raur	?	125–27
line C, 7, 8, 9		Anmima	?	128–30
line D, 3	 (squeeze taken)	Nar . . na . a	?	131

	Hieroglyphic name	Transliteration	Modern name	Number of cast
Ramesseum—continued.				
line D, 4, 5, 6	///////.	Karpu . . .	? . .	132–34
line D. 8 . .	(squeeze taken) .	Kemena . .	Kamoun(Greek)	135
line E, 1, 2, 3.	//// (squeeze taken) .	Atha	? . .	136–38
line E, 5 . .	/// ,, ,, .	Gaba . . .	Gēba	139
line E. 8, 9, 10	///// ////// (squeeze . taken)	M . . . peja .	? . .	140–42
Top of pylon .	?	Khita ? . .	Hittites ? .	143–45
	?	Amar ? . .	Amorites ? .	146–48
Second pylon .	. . . .	with Khita .	Amorite ? . .	149
Medinet Habu— The great façade of royal captive . 1	. . . .	Kesh, chief .	Ethiopian . .	150
(2)	/////// figure and name lost .	? . .	?	—
3	?	? . .	name lost . .	151
4	. . . .	Lebu, chief .	Libyan . . .	152
5	. . . .	Turses, chief	(A southern land)	153
6	. . . .	Mashuash, chief	Maxyes . . .	154
7	. . . .	Tarau, chief .	Toraf	155
8	. . . .	Khita, 'the great vanquished'	Hittite 'taken alive'	156
9	. . . . . .	Amaar, 'the great vanquished	Amorite . . .	157
10	. .	Tákuri, chief of the enemies	Teukrian . .	158
11		Shairedana of the sea	Sardinian ? . .	159
12	//////	Sha (kalsha?) chief	Sicilians ? . .	160
13	. .	Tuirsha of the sea	Etruscans (Turseni) ? . .	161
(14)	////	Pu . . . . . chief	Philistine (hidden by a later wall)	—

	Hieroglyphic name	Transliteration	Modern name	Number of cast
Medinet Habu—continued.				
W. side of entrance	?	? . .	N. African .	162, 3, 5
lower line . .	? (no names)	? . .	Maxyes . .	164, 6
E. side, upper line .	?	? . .	Syrians . .	167, 9
,, ,, .	?	? . .	Teukrian .	168
lower line . .	?	? . .	Asiatic . .	170–73
Inside of doorway .	?	? . .	Teukrian .	174–78
1st court, inside		Amar . . .	Amorites .	. 179–80
outside, S. end	? (11 alike, no names seen)	? . . .	N. Syrian .	. 183
,, near pylon	?	? . . .	N. Syrian .	. 184–88
,, back of pylon	 .	Ar / / / tz / / / /?	El Arzieh .	. 189–90
In court . . .		Pulista . .	Philistines .	. 181–82
E. side, outside scene 6		Takrui . . .	Teukrians .	. 191–93
scene 6 . .	?	? . . .	Philistine .	. 194
			Shairdana .	. 195
			? . . .	. 196
scene 7 . .	?	? . . .	Philistine .	. 197
			? . . .	. 198–99
			Shairdana .	. 200–1
scene 8 . .	?	? . . .	? . . .	. 202–5
			Philistine .	. 206
			Shairdana .	. 207–8
			Shairdana .	. 209–12
scene 9 . .	?	? . . .	Philistine .	. 213–14
Luxor—				
W. outside of Great Hall	No names	Syrian wars with	Hittites .	. 215–62
		and in Naharaina	Mesopotamians	,,
Gizeh—				
Tomb of . . .	 . .	Khufu khaf .	An upper class Egyptian, son of Khufu, Fourth Dynasty	263
			His servants	. 264–68

Contained on about 180 slabs	Karnak	120	besides some extra lettered ones.
	Ramesseum	29	
	Medinet Habu	65	
	Luxor	48	
	Gizeh	6	
	Total heads . . .	268	

PHOTOGRAPHS.	No.	
The four races in tomb of Merenptah, Nos. 772, 773, 774, 775	4	
The negro in tomb of Setí (the only face left visible) No. 776	1	
The four races in tomb of Ramessu III., Nos. 777, 778, 779, 780	4	
Brickmakers, &c., in tomb of Rekhmara (northern race) Nos. 781, 782	2	
Southern races in tomb of Hui (Ethiopia, Soleb, &c.), Nos. 783, 784, 785, 786, 787, 788, 789, 790, 791, 792	10	
Libu (Libyans) Court Medinet Habu, No. 763	1	
Various races in triumphs of Ramessu III. in 1st Court Med. Habu (no names) Nos. 764, 765, 766, 767, 768, 770, 771	7	
Siege of Dapur (Tabor) Ramesseum, No. 753	1	
Chief of Khita, Ramesseum, No. 755	1	
Princess of Pun, Karnak (squeezed also) No. 743	1	
People of Askalon, Karnak (squeezed also) No. 748	1	
People of Khal (Syria) and Kush (Ethiopia), Tell el Amarna, No. 612	1	
Khuenaten, Tell el Amarna, No. 610	1	
Profile and Front of Hyksos Sphinx, from Tanis, Nos. 794. 795	2	
Profile and Front of Hyksos, Faium, Nos. 797, 798	2	
Fish bearers, Hyksos, Tanis, No. 799	1	
		40

Also the following may be worth consulting:—

Tomb of Paheri El Kab. Some bearded figures, perhaps foreigners, among the servants, Nos. 669, 671, 672.	3	
Tomb of Setau. Setau and wife, No. 673	1	
		4

Also the use of the following plates, taken some years ago, is offered to the Committee:—

Semnefer and wife, Gizeh, No. 357	1	
Sphinx, true side view, Gizeh, No. 369	1	
Amenhotep II.. Karnak, No. 297	1	
Seti II., Tomb, No. 252	1	
Merenptah II., Siptah tomb, No. 253	1	
Sides of entry at Medinet Habu, showing position of heads, Nos. 270, 234	2	
Ramessu IV., No. 298	1	
Ramessu IX., No. 261	1	
Modern Egyptians, Nos. 432, 428, 77, 561, 79	5	
		14

Besides a few photographs from Bulak, which are technically the property of the Egypt Exploration Fund.

Photographs at disposal of Committee	58

Colours on the Monuments.

Besides the casts and photographs, notes were made of all colours or traces of colours remaining, both on the remains which I have reproduced and on others the condition of which did not permit of reproduction.

TAHUTMES III. LISTS.—Pylon in axis of Great Hall, Karnak, Busts with shields, alternately red and yellow. Black hair and beard, green band down whiskers. Eyes left red or yellow as the skin, but picked out with black. No difference in type of red and yellow figures, which alternate vertically as well as horizontally.

On N. half of W. side all are alike, pointed beards.

On S. half of W. side all are red apparently. Top line, short square beards. 2nd line, pointed beards. 3rd line, pointed to Mst; short in Ab, Kkt, and St; pointed in Aāh. 4th line, short up to Fusha, two broken, then pointed in Tau . . . and on to end. 5th line, long beard and long hair in front of shoulders; bands on the necks of Bhst, Mesnem, and Mestnu.

SHESHANK'S LIST, and S. wall of Great Hall generally, no colours left.

N. OF GREAT HALL.—*Innua*, people red, horse blue with red spots. *Shasu*, full red, with blue kilts; no difference for hair or eyes. *Tahennu*, orangy-red = decomposed red? *Rutennu*, orange. *Khita* in chariot, orange. *Khita* in lower line, green hair and orange skin, probably decomposed blue and red, which are the only colours used on this wall.

TAHUTMES III.—Pylon. S. of Great Hall. Small figures, apparently all yellow.

RAMESSEUM.—Court. *Khita.* Photo. No. 755. Bearded and beardless figures, both orange (i.e. yellow ochre with Indian red). No certain colour of hair or eyes, apparently all one as skin, certainly no black. Robes, red and blue, broad bands, with narrower white between; or all blue with white border; or narrow bands blue and red. Horses red, blue trappings.

TOMB 35 (Rekhmara).—Photo. Nos. 781–2 Brickmakers, two foreign types: (1) Light blue eyes, pale chocolate and milk skin; hair as skin, only slightly lighter and yellowish; white waist cloth. (2) Brown eyes; skin, slightly paler than Egyptians, Indian red; waist cloth of hide.

	Skin	Eye	Hair	Waist cloth
TOMB 34 (not photographed).				
chief of *Keftu* (Phœnicia) . .	yellow . .	black .	light brown	white, blue and red line borders
chief of *Khita* (Hittite)	brown, not dark	brown .	black, brown beard	white, green, and red borders
chief of *Tunep* (Syria)	same brown .	(gone) .	black . .	white dress, green and red borders
child with him . .	yellow . . .	—	black . .	
followers . . .	brown, not dark	—	black, in 3 tails on shoulders	—
chief of *Kadesh* . .	white . . .	light red-brown	as eye . .	long white dress
Followers alternately red and white				
(Many others are coloured, but nameless.)				

Photo. No.		Skin	Eye	Hair	Beard
	TOMB OF MERENPTAH.—Four races.				
772	Westerns . . .	pale yellow .	blue . .	black	left yellow
773	Blacks	black . . .	red (pupil)	red, black lines	(none)
774	Asiatics	light Indian red	1 blue . . 3 light red	(covered)	black
775	Egyptians . . .	dark Indian red	black	black	(none)
	TOMB OF SETI I.				
776	broken, Westerns	yellow? . .	blue . .	black-brown	—
	Blacks . . .	black . . .	—	red, black lines	—
	broken, Asiatics .	dark yellow, red under beard 1 white, light red on cheek	(gone) . .	black . .	—
	broken, Egyptians	dark red .	black .	black . .	—

TOMB OF SETI II.—As in tomb of Merentaph; but roughly modelled and unpainted.

Photo. No.		Skin	Eye	Hair	Beard
		TOMB OF RAMESSU III.			
777	Asiatics	light red . .	blue . . .	black . .	—
778	Blacks	black . . .	black . .	red, black lines . .	—
779	Westerns . . .	yellow . . .	red, as outlines	black . .	—
780	Blacks	black . . .	black . .	red, black lines . .	—
		TOMB OF HUI.			
789	commander of *Kush*	Egyptian red	brown . .	white, black lines	—
	chief of *Khama*, Soleb	Egyptian red	brown . .	black . .	—
	director of the bulls	Egyptian red	—	—	—
	Pet-ahu . . .	bistre and Indian red	dark brown	black . .	—
	followers . . .	Egyptian red	—	white . .	black, slight
	followers . . .	slightly yellower	—	black . .	—
	followers . . .	bistre and Indian red	black . .	black . .	—
	followers . . .	Egyptian red	black . .	black . .	—
792	Top line, on to end of this :—				
	followers . . .	Egyptian red	black . .	black . .	—
	followers . . .	slightly yellower	black . .	black . .	—
	followers . . .	bistre and Indian red	—	white . .	—
	followers . . .	yellowish Egyptian red	black . .	black . .	—
	followers . . .	Egyptian red	black . .	black . .	—
	followers . . .	slightly lighter	black . .	black . .	—
	followers . . .	bistre and Indian red	black . .	black . .	—
	followers . . .	bistre and yellow ochre	black . .	white . .	—
	followers . . .	bistre and Indian red	black . .	black . .	—
	followers . . .	dark ochre .	black . .	white . .	—
	followers . . .	Egyptian red	black . .	black . .	—
	followers . . .	bistre and Indian red	black . .	black . .	—
	followers . . .	dark yellow ochre	black . .	black . .	—
	followers . . .	dark yellow ochre	black . .	white . .	—
	followers . . .	Egyptian red	black . .	black . .	—
	Lower line, base :—				
		dark yellow ochre	black . .	white, red lines	—
		Egyptian red	black . .	black . .	—
		dark yellow ochre	black . .	—	—
		Egyptian red	black . .	—	—

Photo. No.		Skin	Eye	Hair	Beard
		TOMB OF HUI—*continued.*			
791	Top:—				
	heads gone . .	black-bistre	black . .	—	—
		dark yellow ochre	black . .	—	—
		reddish yellow	black . .	white . .	—
		yellow ochre	black . .	black . .	—
	child	Egyptian red	black . .	black . .	—
		bistre-black .	black . .	black . .	—
		reddish yellow	black . .	black . .	—
		reddish yellow	black . .	black . .	—
	Lower line, base:—				
	Pet-ahu 4	Egyptian red	—	black . .	—
		Egyptian red	—	black . .	—
		yellow ochre	—	black . .	—
		Egyptian red	—	black . .	—
		yellow ochre	—	black . .	—

Photo. No.		Skin	Eye	Hair	Waist cloths
790	Boat with Negroes . 1, 2, 4	black . . .	—	red, black dots	bright red
	3, 5	Egyptian red	—	yellow . .	

Photo. No.		Skin	Eye	Hair	Head
786	Top line:—				
	chiefs of *Uāuta* (kneeling) .	black . . .	black . .	black . .	red
		bistre-red .	black . .	black . .	yellow
	chief of *Amam* (prostrate) . .	black . . .	?	black . .	red
	children of the chiefs 1, 3	black . . .	black . .	black . .	red
	2, 4	bistre-red. .	black . .	black . .	yellow
788	ox boy	Egyptian red	?	?	?
	ring-bearer . .	black . . .	black . .	black . .	yellow
	bag-bearer . . .	Egyptian red	bistre . .	black . .	yellow
	driver	light brown-red	?	black . .	?
	queen	bistre-red .	?	black . .	yellow
787	Top line:—				
	followers . . .	black . . .	black . .	black . .	light red
	followers . . .	reddish bistre	black . .	black . .	yellow
	followers . . .	black . . .	black . .	black . .	light red
	followers . . .	reddish bistre	black . .	black . .	yellow
	followers . . .	black . . .	black . .	black . .	light red
	woman	Egyptian red	black . .	?	?
	woman	black . . .	black . .	black . .	light red
	child in hood . .	all black . .	black . .	black . .	—
	children. . . .	Egyptian red	black . .	black . .	—
		all black . .	—	black . .	—

Photo. No.		Skin	Eye	Hair	Head
		TOMB OF HUI—*continued.*			
785	Top :—				
	ring-bearer . .	Egyptian red	black . .	black . .	yellow
	bag-bearer . . .	black . . .	black . .	black . .	light red
	ring-bearer . .	Egyptian red	black . .	black . .	yellow
	bag-bearer . . .	black . . .	black . .	black . .	light red
	giraffe herds . .	black . . .	black . .	black . .	light red
		Egyptian red	black . .	black . .	yellow
787	Base :—				
	herdsmen from Avau	bistre . . .	black . .	black . .	yellow
		black . . .	black . .	black . .	red
		black . . .	black . .	black . .	yellow
		black . . .	black . .	black . .	red
		light Egyptian red	black . .	black . .	?
		Egyptian red	black . .	black . .	Egyptian red
785	Lowest line, base :—				
	chiefs of *Kush* .	black . . .	black . .	black . .	red
		Egyptian red	black . .	black . .	yellow
		black . . .	grey . . .	black . .	red
		chocolate and milk	grey . . .	black . .	yellow
		black . . .	grey . . .	black . .	red
		red-bistre .	grey . . .	black . .	yellow
784	chiefs of *Kush* .	black . . .	grey . . .	black . .	red
		bistre . . .	grey . . .	black . .	yellow
		black . . .	grey . . .	black . .	red

(Grey eyes, accidental ?, by black laid on before white was dry)

	Skin	Eye	Hair	Robe
MEDINET HABU.—*Palace front.* Casts 150–161. Many quite colourless.				
No. 151	red ? . . .	—	—	—
Lebu	red	red . . .	—	—
Mashuash	red	red . . .	—	—
Tharau	red	—	—	—
Khita	dark browny yellow	—	—	blue
Amar	red	—	—	—
Shairdana	white or yellow ?	—	—	—
Shakalsha	red	—	—	—
Tuirsha	yellow . .	grn. (? blue changed)	—	—

Temple.—2nd court, S.W. corner. *Lebu* red like Egyptians, blue and white robes. Eyes and hair not distinguished.

1st court, E. wall: top line (765) 5th fig., blue head, yellow ? band.

Mid line, 2nd and 5th figs., browny orange skin (765, 764).

Base line (766), all browny orange skin.

Two lines of led captives; top (767) 1 and 2 skin browny orange, 3 red; lower line (768): 1 flesh colour, hair red, 2–5 browny orange, hair black.

Fort of *Amar* (casts 179, 180), skin light red, rather pinker than flesh colour, blue hair or cap.

Inside pylon of 1st court. *Mashuash* (770, 771) red skin.

Remarks on Mr. W. M. Flinders Petrie's *Collection of Ethnographic Types in Egypt*, 1887. *By the* Rev. H. G. Tomkins.

In the autumn of 1886, Mr. Flinders Petrie undertook to execute squeezes and photographs of select types of heads from the wall-paintings and reliefs in temples and tombs on the Nile. Having been requested to prepare a suggestive list of these ethnographic examples, I gladly did so, and it was approved by Prof. Sayce and used by Mr. Petrie, who has brought home a very interesting collection on which, in compliance with the desire of the Committee, I now offer a few remarks. Time and opportunities of sufficient research are lacking, and I therefore crave every reasonable indulgence. But I must heartily thank Mr. Petrie for sending me at the earliest moment his accurate descriptive list, and the photographs mentioned in it, and also Professors Sayce and Maspero for very valuable information and counsel.

We have here to deal with 268 squeezes, from which casts have been made, and with 40 photographs newly taken, besides 21 others which are illustrative mostly of different types of Egyptian races, ancient and modern.

The Egyptians themselves divided mankind in general into four classes, viz. Egyptians; with Cush and others on the south; Libya and others on the west; Syria and others on the north.

In the long course of Egyptian history we have all these to deal with as regards consanguinity (earlier or later), traffic, alliance, and war. Before all come the highly interesting questions which we call prehistoric, but with these we are not now concerned.

My own special task to-day is to determine as far as may be the particular places, or regions, to which our several races, or individuals, belonged. Thus I may hope to prepare the way for scientific inquiry, which will include, I believe, all the leading stems of the human family among the examples of Egyptian portraiture which we have now before us.

It is not derogatory to the merit of the great pictorial works of Champollion, Rosellini, and Lepsius, to say that we have before us in England absolute reproductions of the Egyptian work on which we can for the first time rely with a certainty before unattained.

It will be convenient to follow to-day the order in which the races are placed in the tomb of Merenptah, viz.: Westerns, Southerns, Northerns, Egyptians. I give the usual identifications here.

First. Of tribes reckoned as on the west of Egypt we have here, Libu (Libyans), Mashuash (Maxyans), Tsekuri (Teukrians), Shârdana (Sardinians), Tûrsha (Tyrsenes), Shakalsha (Sicilians), Hâ-nebu (lords of the north, a vague expression used at a later time to designate the Greeks), Dardani (Dardanians), Tahennu ('clear-skinned' or fair people on the coast west of Egypt), and Pulesta, considered to be Pelasgians or Philistines.

I do not take into account the identifications by Brugsch ('Hist.' Eng. tr. ii. 124) of the Shârdana, Tûrsha, Tsekari, Shakalsha, with obscure inland tribes of Asia. He has been answered by Robiou ('Recueil de Travaux,' ii. 58), and by the lamented Lenormant ('Les Origines de l'histoire,' iii. 176), and the opinion of de Rougé and Chabas fully sus-

tained. And I am glad to hear that these identifications have since been withdrawn.

The highly interesting and important bearing of these Egyptian records on the early stages of classic history has been shown by Chabas, de Rougé, and others, and with interesting detail by Lenormant, in some of the last studies of his life, and taken into account by Gladstone in his 'Homeric Synchronism,' but the supreme value of Egyptian lore in this regard has not been adequately recognised at our own universities.

The fair complexions and blue eyes of the Libyan kindreds declare them as sons of Japhet. Like the Hittites, they are involved in the Egyptian destinies, first in war, then in alliance, and at last in marriage. We may hope to know far more about these peoples. In their region French scientific inquirers have been making good research. The cultivated side-locks of the Libu and Mashauasha are very remarkable. Herodotus says that the Maxyans let their hair grow in a long lock on the right side of their head, but shave it on the left. This custom the Egyptians observed in childhood, and the ornamental side-lock is very carefully developed in the royal children. It is always very desirable to notice the front faces which rarely occur, and in the cast of the lower row of captives led by Râmeses III. at Medinet Habu we see one of the Tahennu fronting us, and observe that the hair is cut short on the forehead, forming a fringe, but the side-locks are very long, and most carefully plaited and trained in a long reflex curve on each side, so that the two form together the exact form of an inverted lyre.

Among our examples of these western nations we have no localities mentioned. I will therefore pass on to those names which will bring us to the map, and these we begin to find in the south.

Secondly. The Southerns:—

These we find under the general heads of Cush and Pûn. With the vast extension of the former term we are not here directly concerned, since our Cushites are certainly of Africa. But the variety of races is very strongly marked, as, for instance, in the three photographs of typical heads from the tombs of Merenptah and Râmeses III., Nos. 773, 778, 780. In the first it is odd that the hair should be red with black lines, while the skin is black, the features straight, good, and regular. It is hard to suppose that this does not represent red or brown hair in the original, and it may remind us of a strange race in Nubia, whom Miss Edwards describes as black in complexion but with 'light blue eyes and frizzy red hair,' at Derr, the capital of Nubia; and higher up, '"fair" families, whose hideous light hair and blue eyes (grafted on brown-black skins) date back to Bosnian forefathers of 360 years ago.' These people are 'immensely proud of their alien blood, and think themselves quite beautiful.' ('A Thousand Miles on the Nile.' Tauchnitz ed. ii. 21, 140). Is it possible that there were really red-haired Cushites in the days of Moses? If not, why did the artist paint the skin black but the hair red with black lines? In fact the same thing is true of the negroes in the tomb of Râmeses III., while the Asiatic has black hair in each tomb.

By Pûn we understand, says Brugsch, the southern coast-districts of Abyssinia and the edges of the Somâli coast. The Egyptians in fact applied the term to the country on both sides of the Red Sea, but the local names which we find before us to-day belong mostly to the African Pûn.

In phot. 789, we have the chief of , Kh'āma, that is, Soleb in Nubia, where Thothmes built a celebrated temple.

In Phot. 787, lower line, are cattle with long decorated horns led as tribute by negroes with large feathers on their heads from  which is precisely the name of the Awawa district on the Blue Nile in Abyssinia.

In phot. 786, is another important and ancient name  Amam (Masp. Hist. 82, 85; Brugsch, Zt. 1882, 31), which occurs in the inscription of Una of the Sixth dynasty. It is supposed by Brugsch to be the capital of the Nubian eleventh 'nome,' perhaps the Tama of Pliny (vi. 6).

The first subordinate name we have to consider is, , which we find as No. 11 in the great southern list of Karnak, and also recorded by Seti I., Râmeses II., and Taharqa. But it is not agreed how we are to read this name. Mariette reads it *Arem*, *Arema*, *Alem*, and says that it is the ancient name of Amara, which is the third great division of Ethiopia. I do not doubt it is Orma, south-west of Abyssinia. Cast 87.

 is the second name in the southern lists, following immediately on Cush. Mariette takes it as Adulis, the ancient port of the inlet now called Annesley Bay. But it seems to me that it may well represent the region Adal on the coast of Africa west of Bab el Mandeb. Cast 116.

. No. 20 in the Great List, is identified by Mariette with Zoulla. Is it not, however, rather Dollo in Somâli? Zoulla must represent the classic name 'Αδουλις, already claimed by Mariette for  But the name would also well enough suit Toraf in Abyssinia, if this should be found to agree better with the conditions on examination. Cast 155.

Among the captives of Medinet Habu we find an important Southern name, No. 5, Tursa, or Turses (Brugsch, 'Geogr. Inschr.' ii. 9, and Taf. viii. fig. 19), represented by its chief.

But I must proceed to speak of a very interesting group of eighteen names which Mr. Petrie has selected on account of the individual portraiture which they indicate, so different from a repetition of some conventional head in a long row of local names.

It turns out that these eighteen names all belong to the south, and I trust to show something of the regions which they indicate, taking them as they stand in Mr. Petrie's list.

No. 2. (No. 211, pl. 26, Mar. 'Karnak' ) 36, South List. Mariette very well identifies this Annina with 'Αννινέ of the inscription of Adulis, which seems to be somewhere near Metenna on the left bank of the Atbara river, according to this great Egyptologist. But on the other

hand, Spruner gives Annine as a district inland of the Adulitic Gulf (G. of Tajurrah) and south of the associated name Metine, and I think here we have a much more likely situation. Cast 97.

No. 3. ///, *read*, Debana. This may be found, I think, in Debeni, S.W. of Annine. It is No. 210 of the South List. Cast 98.

No. 4. (209, South List,) Antebeth may probably be found in the same neighbourhood. It seems the same name as No. 37, South List. Cast 99.

Down to this point the names appear to belong to Cush. This may be seen by inspecting Mariette's 'Listes Géogr. de Karnak.' But among the succeeding names—7. Udent, 9. Nehetum, 10. Shatsitum, 11. Set-Hebu, 12. Uruthit, 14. Memthu, and No. 3. Ahûl, 5. Hebnu or Hebu (perhaps), and Mentu or Mendu appear clearly to belong to Pûn. Out of these names of Pûn, six, down to Menthu inclusive, have beards.

No. 7. ////. M. Maspero believes he recognises this in No. 64. South List. 'Karnak' pl. 23 . Uthenit. If in Arabia this seems to be Udein, inland of Zebîd. Cast 100.

No. 9. (No. 62, pl. 22, No. 62, pl. 23. 'Karnak,' where it must be corrected for , Maspero) unknown. Nehetum. Cast 101.

No. 10. , 61 South List, *corr.* into, , Maspero. I have thought it possible that this name exists in Settitte River, Atbara, N.W. Abyssinia. Cast 102.

No. 11. (60, South List, pl. 22, 23, 'Karnak,' *corr.* into , Maspero). But cf. South List, 224. Cast 103.

No. 12. (59, South List, *corr.*, , Maspero. No. 195), Ulthet. Remembering the interchange of *l* and *n*, may this possibly be Wenthit in Shoa? Cast 104.

No. 14. (57, South List). Mariette takes this as certainly the port Μουνδου in Africa between Bab el Mandeb and Guardafui. But there is a Mondu west of Gondokoro, and perhaps we have the maritime Mundu further on in our list. Cast 105.

—No. 2. (198, pl. 26, 'Karnak'). Anhimru. Cast 106.

—No. 3. (54, pl. 23, 'Karnak' Maspero.) . South List, 55), Ahûl, or Auhûl, or

Auhāl. Mariette regards this as the Avalites of the Greeks, south of Bab el Mandeb. This seems very likely. There is a Mount Awalu, east of Shoa, a similar name. Cast 107.

—No. 4. (182, pl. 26, 'Karnak'), Amubes, or, if be det., Abes. Perhaps may be the celebrated god Bes of the land of Pûn. Cast 108.

—No. 5. (181, pl. 26, 'Karnak' , Maspero. Perhaps, as Maspero suggests, a variant of , pl. 24.). The last is No. 77 South List, in which Mariette identified the Κοβὴ ἐμπόριον of Ptolemy, the Hbabo of modern maps. , Hebnu may be the Heban of the Somâli land. Cast 109.

—No. 6. (No. 180, pl. 26, 'Karnak'). The termination is found in Turses (above), and in Purses in the list of Seti, No. 11, which I think may be Mount Farsis, east of the River Hawash in Somâli land. Our Asteses may perhaps be traced by its former element which we find in the rivers Asta-boras (Atbara), Asta-pus, and Asta-sobas, the latter part of which survives as Sobat. These are all eastern tributaries of the Nile, and water the region with which we are concerned. Cast 110.

—No. 7. , Aār or Aāl, 'or rather,' as Prof. Maspero suggests to me, 'Iaro, the river.' Now we find on the pillars of the temple at Soleb, built by Thothmes III. Is it possible that is marked in maps as Irau, near Soleb on the Nile? Cast 111.

Next we have , doubtless the No. 64, South List in Pûn. If the initial vowel has dropped, it may very well be Dand in the Somâli land, east of Harar. Cast 113.

The next name is to be read , Mentu. It is No. 80 in South List, and it seems to me that it may be the Mundu mentioned under No. 14, above, in our list. Cast 114. The last name is defective.

It is very clear in the main to what regions our series of eighteen heads belong. I have hope to know more before the Manchester meeting, but have not yet seen the squeezes or casts from them, as they are not yet ready, and my study of this part of our subject has been very much restricted in time and opportunity. I wish, however, to give material for further study in this hasty abstract.

In the Egyptian portraiture of southern peoples, we have the same striking contrasts of various races as in the Africa of to-day. Take as extreme terms the refined faces and upright slender figures of the chiefs

of Pûn, in phot. 743, from the wall of Horemheb of the Eighteenth dynasty, and any of the utter negroes of the tableaux.

There is a point in this phot. 743 to which I wish to direct attention. These ambassadors, nobles of Pûn, wear the peculiar pointed beard, curved forward, which the Egyptians assigned to their gods. Does not this well agree with the belief on their part, that this was the divine land where their golden age of Horus and his servants had been, and whence sprang the gods and the godlike? And does not this actual survival of the beard sacred in Egypt on the chins of the noblesse of Pûn point to the historic character which some Egyptologists have ascribed to the Horus-legend?

It is worth while to notice that on the pillars of the temple at Soleb one head alone of the captives bearing the name-rings of tributary places wears this peculiar beard. It is the chief of , a place which I have mentioned above under the name  No. 7 of the latter part of the series of 18. (Leps. 'Denkm.' Abth. iii. Bl. 88.)

I do not venture to affirm that this is a man and place of Pûn, but the beard deserves notice.

III. Northerns. We will take first the nomadic tribes whom the Egyptians encountered first in the open desert beyond their fortified frontier line to the east of the Delta.

1. Here we have the  *Menti of the Sati*; the Bedâwin of Sinai, Palestine, and the Hauran, as M. Maspero defines the expression; the former word meaning shepherds, the latter bowmen. Cast 95.

I have sometimes thought it worth inquiry whether the Sati-u (or Sitiou, as M. Maspero vocalises the name) are to be connected with the Suti, the bow-bearing desert folk of whom Fr. Delitzsch writes ('Wo lag das Paradies?' 235). It is to be borne in mind that the hordes of barbarians who mastered Lower Egypt under the Hyksôs were called 'in a general way, Mentiou, the shepherds, or Sitiou, archers' (Maspero, 'Hist.' 4th ed. 164), as their chiefs were called Hyksôs, from the Egyptian *Hiq*, king, and *Shasu*, of whom we next speak.

2.  *Shāsu*, plunderers. We meet with these people from the frontiers of Egypt far away into Syria. They seem a Semitic people, and are considered generally as Arabs, and play a most important part from the earliest dynasties of Egypt downwards. Casts 40–48.

3. Next we will take the geographical terms which, vague at best, were long established and well recognised.  *Ruthen hirt*, Upper Ruthen. Southern Syria generally identified with Palestine.

4.  *Ruthen Khert*, Lower Ruthen. The country north of Upper Ruthen. The whole Ruthen region embraces, as M. de Saulcy has pointed out, the Syria of Strabo; all Palestine with the Phœnician coast to the west from el-Arish to Silicia, and to the east Arabia Petræa, Moab, Ammon, the Haûran, the Ledja, and the territory of Damascus. Indeed some captives even from the Euphrates Valley are vaguely reckoned among the Ruthennu. It is the term that distinguishes the Aramaic lordship of Syria from the mastery of those invaders from the

north, the Kheta and allied races, of whom we must presently speak. Casts 69, 70.

5.  *Lemenen.* This word was at first read as Remenen, and taken for Armenia, but it is now generally accepted as equivalent to Lebanon. The men of Lebanon—Semitic people in long robes with capes, and wearing hoods bound with fillets—are represented as hewing down tall pine trees in their mountains for Seti I. Casts 88–93.

6. The Lebanon leads us to  *Keft,* Phœnicia.—This is a very interesting and important designation, which appears to me to linger still in the name Karkafta, near the coast north of Ruad, the ancient Arvad.

The Greek legend of Kêpheus, embodied the name and history of Keft. The connection between Phœnicia and Pûn is very important. In Egyptian tableaux the nobles of Keft bring splendid vessels of gold and other precious materials. They wear beautifully embroidered kilts, with fringes and sashes, and their hair is trained into long locks on both sides of the head.

7.  Khal, or Khar, denotes Northern Syria.—The name has been traced to the Semitic *Akharru,* the hinder, or western, land. The *r* and *l* are very interchangeable, and at all events we meet the form Khal in the river Khalus and other forms, as Khalkis, for instance. The people of Khal have a marked Semitic aspect, and the dignified fashion of drapery which distinguishes their kindred.

8.  *Am'ăr,* the Amorite.—We find this name in many and important relations both in the Bible and without. In Egyptian record it is remarkably locked in with the geographical relations and doings of the Kheta, both in Northern Syria and in the south. It appears also in local connection with the Euphrates, and with the kingdom of Damascus. The Amorite is bearded and has strongly marked features, and wears the same long robe and cape as the inhabitants of the Lebanon, and the Semitic people of Ascalon, and the like. Casts 62–5, 86, 146–8, 157, 179–80.

9.  *Kheta*; *Kheth,* the Hittite.—Here we certainly have an intrusive and conquering race, who in course of time supplanted the Ruthen in the dominion of Syria, and, as we know, ran almost a successful race with the Egyptians, merging their hostile relations into those of political and matrimonial alliance. At length the Hittite power was utterly broken by Assyria under Sargon, and we now have to gather their story from Egyptian monuments and Assyrian cylinders, until we may obtain and read their long lost memorials. Casts 49–58, 76–7, 143–5, 156.

Dr. Birch used compendiously to call the Kheta Tatars, and this expresses well their aspect with yellow beardless faces, and long pigtails or scalp locks. Everything belonging to the Hittites is now very deservedly in request. For my own humble part, I have been endeavouring to identify in the Northern Syrian List of Karnak the sites of their

buried fortresses and sanctuaries, and I trust that the time is near when the region of the Orontes and Upper Euphrates will receive due attention.

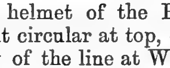
I would notice that besides portraits of Hittites by Egyptian artists we have some by their own sculptors, notably of two potentates, whether gods or otherwise, on a stone photographed by my friend Dr. Gwyther, where they are sitting opposite to each other at a cross-legged table. Their headdress is drum-shaped, and resembles that worn by the unsemitic Babylonian King Murduk-nadin-akhi in that beautiful relief-sculpture in the British Museum. The faces are both ugly enough, the middle of the face protruding, as in the Hittite king at Medinet Habu, but with an exaggerated resemblance of that profile. It is well worth while, I think, to study the 'ugly faces' from Tarsus, in Barker's 'Lares and Penates,' and consider what he says, and quotes from Mr. Abington, in connection with Huns and Hittites.[1] And I would refer to the woodcuts in the 'Rob Roy on the Jordan,' pp. 241, 255, where the barbarians of Huleh Lake have pigtails and long locks like the Hittites. There is also a woodcut given as a frontispiece in Captain Cameron's work entitled 'Our Future Highway,' representing a Kurdish shepherd of Northern Syria, who wears a high cap exceedingly like the headdress of the King Kheta-sar whose daughter Rameses II. married. The people of Huleh who treated Mr. McGregor so roughly were most of them tattooed.

10. . *Pulesta-u.* Since this people have been identified with the Philistines of the coast-land of Palestine (who, indeed, gave that name to the country), and this opinion, earnestly contested by Chabas, is upheld by Maspero and others, it is right to include them in this connection among the northern peoples. Casts 181–2, 194, &c.

The distinctive helmet of the Pulesta was not contracted so as to resemble a crest, but circular at top, of the same shape as the old caps of the British infantry of the line at Waterloo, and before the time of our Queen. This may be seen where a front-face occurs here and there in the scenes of combat.

Lenormant saw in the last name of the allies in the great Harris Papyrus 'the Pelasgians of Crete, whence issued the Philistines' ('Les Orig.,' iii. 127.)

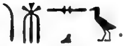
Now we will turn to special places mentioned in our list which belong to Palestine or Syria.

No. 1, we have . *Luza* ('Geog. Inschr.' ii. 75, Taf. xxiii. 273), which Brugsch identifies with a town called by Eusebius Λουζά near Sichem. Casts 18–20, 24–27.

It was, however, a fort in northern Syria, perhaps at Kalb Louzeh, near Edlip.

No. 2. . *Aia* is the next name. I think this is the Aia of the North Syrian list of Thothmes III., which I take to be probably Kefr Aya, south of Homs. Casts 21–23.

[1] *Lares and Penates.* London: Ingram Cooke & Co., 1853 203 *et seq.*

No. 4. . *Dimesqu*, Damascus. This is No. 13 of the South Syrian Karnak List of Thothmes III. Cast 117.

No. 5. . *M'ārm'ā.* Merom, South Syrian List, No. 12. Casts 121-3.

No. 6. . *Dāpur.* This fortress was supposed by Chabas to be Debir in the south, but it is now generally agreed to be Tabor, where the name remains as Debûrieh. The representation of the siege by Râmeses II. is highly important in many ways. We have part of the subject in phot. 753. Cast 124.

It is expressly called in the inscription, 'Dāpur in the land of the Amorites,' yet it is defended by pig-tailed Hittites.

No. 7. This and some that follow are from the celebrated triumphal inscription of Sheshonq recording his conquests in Palestine. Perhaps this , Khaniniā (93 in the list), may be Khŭrbet Hanûneh, *Sheet XIV. Kr.*, *Name Lists*, p. 233, or possibly, Beit Hanîna, *XVII. Mt.* There is an Ananiah of Benjamin mentioned in Neh. xi. 32. Cast 36.

No. 8. This is the celebrated name  *Iudah-melek*, No 29 in Shishak's List. Cast 38. I think it is el Yehûdieh, east of Joppa.

No. 9.  *Adir*, or *Adil*, No. 28 in Shishak's List. Cast 39, et Tîreh.

No. 10. , *Asqalunā*, Askalon. We have the surrender of this celebrated place in phot. 748. Casts 30-33.

No. 11. . Inuā, or Inu, one of the three important fortresses of Ruthen taken by Thothmes III. Casts 78-81.

No. 12. Another celebrated fortress, taken by Seti I., that of , *Kan'ān'ā*, Cana'an. This interesting site has been identified by Captain Conder, R.E., at Khŭrbet Kan'an, six miles south of Hebron.

I have endeavoured to give in this rough and hasty sketch a groundwork of identifications of races and localities for the help of students of the subject now before us, and have classified the material in the way that seemed to me most useful.

Report of the Corresponding Societies Committee, consisting of Mr. FRANCIS GALTON (*Chairman*), Professor A. W. WILLIAMSON, Sir DOUGLAS GALTON, Professor BOYD DAWKINS, Sir RAWSON RAWSON, Dr. J. G. GARSON, Dr. J. EVANS, Mr. J. HOPKINSON, Professor R. MELDOLA (*Secretary*), Mr. W. WHITAKER, Mr. G. J. SYMONS, General PITT-RIVERS, Mr. W. TOPLEY, Mr. H. G. FORDHAM, *and* Mr. WILLIAM WHITE.

THE Corresponding Societies Committee beg to report that the Conferences of Delegates were held during the Birmingham meeting of the British Association at 3.15 P.M. on Thursday, September 2, and Tuesday, September 7, 1886, in the library of the Medical Institute.

The following is the list of Delegates nominated to attend the meeting and the Societies represented by them:—

Rev. H. H. Winwood, M.A., F.G.S.	Bath Natural History and Antiquarian Field Club.
Prof. W. Hillhouse, M.A., F.L.S.	Birmingham Natural History and Microscopical Society.
Rev. H. W. Crosskey, LL.D., F.G.S.	Birmingham Philosophical Society.
Prof. W. Ramsay, Ph.D., F.C.S.	Bristol Naturalists' Society.
Mr. H. T. Brown, F.G.S., F.C.S.	Burton-on-Trent Natural History and Archæological Society.
Mr. Henry Heywood, F.C.S.	Cardiff Naturalists' Society.
Rev. J. M. Mello, M.A., F.G.S.	Chesterfield and Midland Counties Institution of Engineers.
Mr. J. G. Goodchild, F.G.S.	Cumberland and Westmorland Association for the Advancement of Literature and Science.
Mr. M. G. Stuart	Dorset Natural History and Antiquarian Field Club.
Mr. A. S. Reid, M.A., F.G.S.	East Kent Natural History Society.
Mr. J. Martin White	East of Scotland Union of Naturalists' Societies.
Prof. R. Meldola, F.R.S., F.C.S.	Essex Field Club.
Mr. J. B. Murdoch	Geological Society of Glasgow.
Mr. John Hopkinson, F.L.S., F.G.S.	Hertfordshire Natural History Society and Field Club.
Dr. Thomas Aitken	Inverness Scientific Society and Field Club.
Rev. E. B. Savage, M.A.	Isle of Man Natural History and Antiquarian Society.
Mr. F. T. Mott, F.R.G.S.	Leicester Literary and Philosophical Society.
Mr. Isaac C. Thompson, F.R.M.S.	Liverpool Microscopical Society.
Mr. G. H. Morton, F.G.S.	Liverpool Geological Society.
Mr. Mark Stirrup, F.G.S.	Manchester Geological Society.
Mr. A. S. Eve	Marlborough College Natural History Society.
Mr. D. Corse Glen, C.E., F.G.S.	Natural History Society of Glasgow.
Prof. G. A. Lebour, M.A., F.G.S.	North of England Institute of Mining and Mechanical Engineers.
Mr. W. Dunnett Spanton, F.R.C.S.	North Staffordshire Naturalists' Field Club.
Mr. H. J. Eunson	Northamptonshire Natural History Society and Field Club.
Mr. Matthew Blair, F.G.S.	Paisley Philosophical Institution.
Dr. H. Muirhead, LL.D.	Philosophical Society of Glasgow.

Mr. R. G. Hobbes	Rochester Naturalists' Club.
Dr. R. W. Felkin, F.R.G.S. . .	Scottish Geographical Society.
Rev. P. B. Brodie, F.G.S. . .	Warwickshire Naturalists' and Archæologists' Field Club.
Rev. E. P. Knubley, M.A. . .	Yorkshire Naturalists' Union.
Mr. J. W. Davis, F.G.S. . . .	Yorkshire Geological and Polytechnic Society.

At the first Conference the chair was taken by Dr. A. W. Williamson, LL.D., F.R.S., General Treasurer of the British Association, the Corresponding Societies Committee being represented by Captain (now Sir) Douglas Galton, F.R.S., General Secretary of the Association, Dr. Garson, Mr. John Hopkinson, F.L.S., and Professor R. Meldola, F.R.S., Secretary.

The Secretary read the Report of the Corresponding Societies Committee which had been presented to the Council of the Association.

The Chairman made some remarks explanatory of the objects of the Conference of Delegates, and suggested that among other subjects of investigation in which it might be useful to secure the co-operation of the local Societies was that of injurious insects, already so much studied by Miss E. A. Ormerod.

The Secretary also made some observations in explanation of the constitution of the Corresponding Societies Committee and the relations existing between the Conference of Delegates and the British Association.

Some remarks were made by Mr. J. W. Davis and others with reference to the advisability of securing the co-operation of the local Societies for the purpose of investigating British barrows and other prehistoric remains. This suggestion had been put forward at the Aberdeen Conference last year by Professor Meldola, and a Committee was about to be formed by Section H for carrying out this object.

Mr. H. Heywood considered that the relationship now existing between the British Association and the Corresponding Societies had already been of great assistance to the Societies themselves. In the case of his own Society (Cardiff) they had been able to assist one of the committees (erratic blocks) brought under the notice of the Aberdeen conference last year.

Professor Lebour stated that many of the local Societies, such as the North of England Institute, which he represented, were composed of engineers connected with large works, who might make useful investigations, which would be facilitated if backed up by the authority of the British Association. For this reason he hoped that other subjects besides natural history, geology, or anthropology would be recognised at the Conferences.

Captain Galton explained that the object of the Conference of Delegates was to bring the Corresponding Societies into direct communication with *all* the Committees of the British Association, to which the local Societies or individual members of these might render assistance. This could of course be only effected by degrees, but he suggested that as a preliminary step it might be found useful to place the Delegates on the Committees of those Sections in which they or their Societies had the most interest.

Dr. Williamson supported this proposition, and the Secretary took down the names of the Delegates to be attached to the various Sectional Committees.

Professor Hillhouse and Dr. Garson expressed their willingness as

Secretaries of Sections D and H respectively to propose Delegates as members of the Sectional Committees.

Mr. Hopkinson suggested that among other methods of promoting work among local Societies it might be found advantageous for the Delegates themselves to make suggestions at the Conference which might lead, through the proper channels, to the formation of new Committees by the British Association. He stated that his own Society (Hertfordshire) had already rendered material assistance to the Erratic Block Committee of the Association, and they hoped to render similar service to the Underground Water Committee.

The following resolution, framed with the object of keeping the Corresponding Societies informed of the work being done by the British Association Committees, was moved by Dr. Garson, seconded by Captain Galton, and passed unanimously:—

'That the Secretary of the British Association be requested to send a list of the several Committees appointed by the Association to each of the Delegates of the Corresponding Societies, or to the Secretaries of these Societies, as soon as possible after the meeting of the Association, together with a copy of the proceedings of the meetings of the Conference of Delegates.'

At the second Conference the chair was taken in the absence of Dr. Williamson by Professor Boyd Dawkins, F.R.S., the Corresponding Societies Committee being represented by Dr. Garson, Mr. John Hopkinson, F.L.S., and the Secretary, Professor R. Meldola, F.R.S.

The Secretary read the minutes of the proceedings of the first Conference, and it was stated that, in accordance with the decision then arrived at, the Delegates had been placed on the respective Sectional Committees as 'Delegate Members.'

The Chairman directed attention to the kind of work which might be done at the Conferences, stating that, as a member of the Council of the British Association, he knew that the Association was anxious to consolidate the work of the local Societies. He suggested that the best mode of procedure would be to take the different Sections *seriatim* and hear the recommendations forwarded by the Committees of these Sections, together with suggestions by the Delegates respecting the lines of investigation in which the local Societies could take part.

Sections A and B.

No recommendations from the Committees of these Sections having been forwarded to the Secretary of the Conference, the Chairman invited suggestions from the Delegates.

Luminous Meteors.—Mr. F. T. Mott suggested that much useful work might be done if the local Societies would undertake to record systematically the appearance, position, direction, &c., of luminous meteors.

The Secretary stated that a Committee of the British Association was for many years in existence for the purpose of carrying out these observations, but, for some reason unknown to him, the Committee appeared now to have ceased its labours.

Magnetic and Tidal Observations.—Mr. J. Martin White suggested that some of the local Societies which were favourably situated for the purpose might undertake systematic observations of local tidal and magnetic phenomena.

Meteorological and Phenological Observations.—Mr. Heywood stated that many valuable meteorological observations were buried in the log-books of steamships, and suggested that some of the local Societies might render good service to meteorology by examining these books and keeping records of any important entries. Mr. Hopkinson pointed out two ways in which the local Societies might advance meteorological science. In the first place he thought that many observers in different parts of the country might be in the habit of recording the rainfall or other meteorological phenomena without communicating the results to Mr. Symons. Good service would be rendered if the Corresponding Societies would find out such observers and put them into communication with Mr. Symons.[1] In the next place he suggested that observations of the time of flowering of plants, first appearances of birds and insects, &c., might be systematically recorded and forwarded to the Royal Meteorological Society [2] by those observers who had not hitherto been in the habit of communicating their results to that Society.

SECTION C.

Mr. C. E. De Rance, F.G.S., attended the Conference on behalf of the Committee of this Section. The three following recommendations were forwarded by the Secretary of the Section:—

Sea-coasts Erosion.—'That Messrs. R. B. Grantham, C. E. De Rance, J. B. Redman, W. Topley, W. Whitaker, J. W. Woodall, Major-General Sir A. Clarke, Admiral Sir E. Ommanney, Sir J. N. Douglass, Captain J. Parsons, Captain W. J. L. Wharton, Professor J. Prestwich, and Messrs. E. Easton, J. S. Valentine, and L. F. Vernon Harcourt be reappointed a Committee for the purpose of inquiring into the Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other Material in that Action; that Messrs. De Rance and Topley be the Secretaries.'

Underground Waters.—'That Professor E. Hull, Dr. H. W. Crosskey, Captain Douglas Galton, Professor J. Prestwich, and Messrs. James Glaisher, E. B. Marten, G. H. Morton, James Parker, W. Pengelly, James Plant, I. Roberts, Fox Strangways, T. S. Stooke, G. J. Symons, W. Topley, Tylden-Wright, E. Wethered, W. Whitaker, and C. E. De Rance be reappointed a Committee for the purpose of investigating the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Water supplied to various towns and districts from these formations; and that Mr. De Rance be the Secretary.'

Erratic Blocks.—'That Professors J. Prestwich, W. Boyd Dawkins, T. McK. Hughes, and T. G. Bonney, Dr. H. W. Crosskey, and Messrs. C. E. De Rance, H. G. Fordham, J. E. Lee, D. Mackintosh, W. Pengelly, J. Plant, and R. H. Tiddeman be reappointed a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation; and that Dr. Crosskey be the Secretary.'

Mr. De Rance described the above three inquiries undertaken by Section C, in which it was thought the Corresponding Societies could

[1] G. J. Symons, F.R.S., 62 Camden Square, London, N.W.

[2] 30 Great George Street, London, W.

render valuable assistance. Forms of inquiry had been circulated largely by these Committees, and it was suggested that any work done by the Corresponding Societies should be on these forms printed by the British Association. Mr. De Rance stated that forms would always be supplied to the Secretaries of Corresponding Societies applying for them.

Dr. Crosskey made some remarks explanatory of the work of the Erratic Block Committee. He stated that the assistance of the local Societies would be particularly valuable in this inquiry, and that he would be happy to supply the necessary forms to the Corresponding Societies in the hope that they would be filled up. He urged upon the Delegates the necessity for preserving these boulders, which were everywhere being broken up and were rapidly disappearing from off the face of the country.[1]

Earth-tremors.—Professor Lebour stated that for some time past the North of England Institute of Mining and Mechanical Engineers had had a Committee actively engaged on the subject of earth-tremors and their possible connection with mine explosions. This subject was naturally related to those of Sections A, C, and G of the British Association, and its investigation might be powerfully promoted by them. Some of the Corresponding Societies might aid greatly in making and recording observations on earth-tremors in various parts of the country. The more extensive the area over which such observations were made (if by competent observers and with suitable instruments) the more valuable they become; but it was very important that there should be some general understanding between the observers in different parts of the country, in order that some degree of that uniformity which is so desirable in matters of this kind should be attained. The cost of the expensive instruments necessary would be much lessened if large numbers of them were used. The question of earth-tremor observations was only one of many in which the engineering societies and the British Association could be mutually useful, the former carrying out the work and the latter lending the influence of its official recognition and support.

The Rev. J. M. Mello stated that colliery proprietors were generally unwilling to spend money in investigations unless some very specific form of inquiry was circulated.

Mr. Hopkinson remarked that the Corresponding Societies, if supplied with the necessary forms, would no doubt be willing to circulate them among their members. Mr. Heywood thought the suggestion for observing and recording earth-tremors a most valuable one, and he remarked that the Cardiff Society would be happy to assist in the investigation if the formation of a Committee was sanctioned by the Association.

Section D.

The Committee of this Section was represented by Professor W. Hillhouse, M.A., F.L.S.

Preservation of Native Plants.—In reply to a question by the Secretary,

[1] The addresses of the Secretaries of these three Committees are:—

Underground Waters .	C. E. De Rance, F.G.S., A.I.C.E., 28 Jermyn Street, London, S.W.
Erratic Blocks . .	Rev. H. W. Crosskey, LL.D., F.G.S., 117 Gough Road, Edgbaston, Birmingham.
Sea-coasts Erosion .	Wm. Topley, F.G.S., A.I.C.E., 28 Jermyn Street, London, S.W.

Professor Hillhouse stated that in response to the inquiries which he had circulated among the Delegates and others likely to furnish information he had received details from twelve or fourteen localities recording between two and three hundred disappearances of plants. Mr. Stirrup stated that for years past a great destruction of plants had been going on in the Manchester district, and the local Societies had found it necessary to strongly inculcate among their members the necessity of preventing this extermination. Mr. Hopkinson remarked that a similar rule had been always observed by the Hertfordshire Society with respect both to animals and plants, and he thought that all the local Societies should adopt it. Mr. Mott pointed out that one practical result illustrating the benefit of Professor Hillhouse's resolution had been the omission of the localities of all the rare ferns and orchids from the flora of Leicestershire, which his Society was just about to publish.

Local Museums Committee.—Mr. Mott stated that a joint Committee, composed of representatives of Sections C and D, had been recommended for appointment for the purpose of reporting upon the provincial museums of the United Kingdom. The work of this Committee would be much facilitated by the co-operation of the local Societies, and he hoped that the Delegates would bring the matter under the notice of their respective Societies. The Committee consists of Mr. V. Ball, Mr. H. G. Fordham, Professors Haddon and Hillhouse, Dr. Macfarlane, Professor Milnes Marshall, Mr. Mott (Secretary), Dr. Traquair, and Dr. Henry Woodward.

In reply to a question as to whether the work of this Committee was to be confined to public or to extend to private museums, Mr. Mott stated that it might be found desirable to extend the report to some few private museums.

The Chairman remarked that the Local Museum Committee was one of the most important that had yet been formed. The local museums of this country were generally in a most deplorable state, and one of the first things to be done was to exclude from such collections all extraneous specimens that were not truly local. According to his experience he had found that it was impossible for a local Society to flourish and at the same time to carry on a large museum successfully. The two organisations should be independent, but at the same time it was most desirable that the objects collected by local Societies should be handed over to the nearest local museum. With reference to this question of local museums, he considered that we in this country were much behind Germany, America, and France.

A short discussion took place with reference to the naming of specimens in local museums, in which Mr. Eve, Mr. Hopkinson, and the Chairman took part.

SECTION H.

The Committee of this Section was represented by Dr. Garson, who stated that one Committee which was about to be formed on the recommendation of their Section had arisen from the suggestion made by Mr. J. W. Davis at the last Conference, viz.—

Prehistoric Remains.—The following is the resolution sent up to and adopted by the Committee of Recommendations:—'That Sir John Lubbock, Dr. R. Munro, Mr. Pengelly, Professor Boyd Dawkins, Dr. Muirhead, and Mr. J. W. Davis be appointed a Committee to ascertain and

record the localities in the British Islands in which evidence of the existence of prehistoric inhabitants of the country is found.'

Professor Meldola stated that three years ago he had brought this subject under the notice of the Delegates in a paper which he had read at the Southport meeting of the Association, and which had been published in abstract in the volume of Reports for 1883, and *in extenso* in the 'Transactions' of the Essex Field Club. He remarked that the work which the Committee proposed to undertake was of the greatest national importance in view of the great destruction of ancient remains that had been going on for many years.

The Chairman remarked that the subject was undoubtedly one of great importance, and some of the local Societies had already commenced to record the position of these remains on the ordnance maps. He stated that according to his experience the 1-inch map could be used, but the 6-inch map would be found much better. One desideratum in the work was a good system of symbols; such a system had been employed in a map of ancient remains recently published in France, and he stated that he should be happy to place this system at the disposal of the Committee. He added that he was glad to be able to announce that he had succeeded in getting an Act passed for the preservation of the ancient monuments of the Isle of Man.

Preservation of Stonehenge.—Dr. Garson stated that the Committee of Section H had forwarded a resolution to the Committee of Recommendations with reference to the preservation of Stonehenge, and, pending its consideration by this Committee, it had been suggested that it should also be brought under the notice of the Corresponding Societies through their Delegates, with the object of these using their influence, as far as possible, for the preservation of this and other monuments throughout the country. The following is the resolution referred to:[1]—'That the attention of the proprietor of Stonehenge be called to the danger in which several of the stones are at the present time from the burrowing of rabbits, and also to the desirability of removing the wooden props which support the horizontal stones of one of the trilithons, and, in view of the great value of Stonehenge as an ancient monument, to express the hope of the Association that some steps will be taken to remedy these sources of danger to the stones.'

This resolution had originated last April during a joint meeting of the Geologists' Association and the Hampshire Field Club on Salisbury Plain, when copies were ordered to be forwarded to the proprietor, to the Inspector of Ancient Monuments, and to the Secretary of the Corresponding Societies Committee of the British Association. The proprietor of these valuable remains had hitherto refused to take advantage of the Ancient Monuments Act, though repeatedly requested to do so, neither had he paid due attention to their proper preservation, so that it had been thought desirable to move the foregoing resolution which had been sent to the proper quarter for confirmation by the General Committee of the Association.

Election and Retention of Corresponding Societies.—At the termination of the Conference Mr. J. W. Davis raised the question whether a

[1] This resolution was adopted by the Committee of Recommendations and confirmed by the General Committee.

Corresponding Society, when once admitted by the Association, should not always be retained on the list, or at any rate so long as the Society kept up its scientific activity.

The question was partially answered at the Conference by the Secretary, and the Corresponding Societies Committee having since taken the matter under their consideration beg to direct attention to Rule 4, which states that—'Every Corresponding Society shall return each year, on or before June 1, to the Secretary of the Association a schedule properly filled up, which will be issued by the Secretary of the Association, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.' The Committee in accordance with this rule see no reason why a Corresponding Society, when once admitted, should not be retained as long as it maintained its activity, but it is expected that each Society will make an annual return of the papers published by it on the schedule supplied for that purpose.[1] Some few of the Societies which were enrolled in 1885 did not appear in the list published last year in the Birmingham Report, the reason for this being that the Secretaries had neither returned their schedules with the required entries nor taken any notice of a second application asking whether it was the wish of their Societies to be retained as Corresponding Societies. The Secretary of the Committee had accordingly concluded that these Societies desired to withdraw.

Attendance of Delegates.—Another question raised at the last Conference of Delegates—viz., whether each of the Corresponding Societies is expected to send a Delegate annually to the meeting of the British Association—has also been considered by the Corresponding Societies Committee. In accordance with Rule 6, a 'Corresponding Society has the right to nominate any one of its members, who is also a Member of the Association, as its Delegate to the annual meeting of the Association, who shall be for the time a member of the General Committee.' The sending of a Delegate is not therefore compulsory, and the Committee are of opinion that an occasional failure on the part of a Corresponding Society to send a Delegate to the meeting of the Association should not disqualify that Society for retention on the list of Corresponding Societies. It is hoped, however, that these Societies will use their best endeavours to send Delegates to represent them. It is expected that every Delegate nominated and present at the meeting of the Association will attend the Conferences.

The Corresponding Societies Committee have in conclusion to report that the Council of the British Association have sanctioned the presentation of the complete volume of Annual Reports to each of the Corresponding Societies so long as these are retained on the list.

It is recommended that all the Societies on last year's list should be retained; also that the Croydon Microscopical and Natural History Club and the Manchester Geographical Society should be enrolled as Corresponding Societies.

[1] In cases where no papers have been published during the year it is only necessary to state this fact on the schedule.

The Corresponding Societies of the British Association for 1887–88.

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Barnsley Naturalists' Society, 1867	Barnsley Nat. Soc.	W. E. Brady, 1 Queen Street, Barnsley, Yorks.	80	2*s.*	6*s.* and 10*s.* 6*d.*	Transactions, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	Rev. H. H. Winwood, Royal Literary and Scientific Institution, Bath	95	5*s.*	10*s.*	Proceedings, annually.
Bedfordshire Natural History Society and Field Club, 1875	Beds. N. H. S. F. C.	T. Gwyn Elger, F.R.A.S., Hempston, Beds.	75	None	5*s.*	Transactions, every two years.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	William Swanston, F.G.S., 50 King Street, Belfast	30	None	5*s.*	Report and Proceedings, annually.
Birmingham Natural History and Microscopical Society, 1858	Birm. N. H. M. Soc.	W. N. Wilkinson and William P. Marshall, Mason College, Birmingham	211	None	1*l.* 1*s.*	'Midland Naturalist.' Monthly.
Birmingham Philosophical Society	Birm. Phil. Soc.	R. Levett and J. H. Poynting, Medical Institute, Birmingham	124	None	1*l.* 1*s.*	Proceedings, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	University College, Bristol. Professor Adolph Leipner, 47 Hampton Park, Clifton, Bristol	245	5*s.*	10*s.*	Proceedings, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	Burton Institute. G. Harris Morris, Ph.D., F.I.C., Avondale, Alexandra Road, Burton-on-Trent	132	None	5*s.*	Annual Report. Transactions occasionally.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	R. W. Atkinson, 44 Loudoun Square, Cardiff	450	None	10*s.*	Report and Transactions, annually.
Chester Society of Natural Science, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum. G. R. Griffith, Grosvenor Street, Chester	560	None	5*s.*	Annual Report. Proceedings every three or four years.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 13 Cavendish Street, Chesterfield	258	1*l.* 1*s.*	Members 31*s.* 6*d.*; Subscribers 21*s.*; Associates and Students 20*s.*	Transactions, quarterly.
Cornwall, Mining Association and Institute of, 1884	Cornw. Min. Assoc. Inst.	William Thomas, Tuckingmill, Camborne	240, and 18 Associates	None	Minimum: Members, 10*s.* 6*d.*; Associates, 2*s.* 6*d.*	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	G. B. Millett, Penzance	109	None	1*l.* 1*s.*	Report and Transactions, annually
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	W. Low Sarjeant, 7 Belgrave Road, South Norwood, S.E.	270	None	10*s.*	Proceedings and Transactions, annually.
Cumberland and Westmorland Association for the Advancement of Literature and Science, 1876	Cumb. West. Assoc.	Robert Crowder, M.A., Stanwix, Carlisle	1,283	None	Assoc. Memb., 5*s.*; Memb. of affiliated Soc., 6*d.*	Transactions, annually.

SELECTED LIST OF SOCIETIES, &c. (*continued*).

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	M. G. Stuart, Manor House, Hinton Blewett, near Bristol	180	None	10*s.*	Proceedings, annually. Additional volumes, occasionally.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1876	Dum. Gal. N. H. Soc.	Dumfries. J. Wilson, 3 Norfolk Terrace, Dumfries	226	2*s.* 6*d.* (Gentlemen only)	2*s.* 6*d.*	Transactions and Journal of Proceedings, every two years.
East Kent Natural History Society	E. Kent N. H. Soc.	William P. Mann, 6 High Street, Canterbury	75	None	Gentlemen, 10*s.*; Ladies, 5*s.*	Transactions, occasionally.
East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, 12 Townsend Crescent, Kirkcaldy, N.B.	10 Societies, 1,152 Membs.	None	Assessment of 4*d.* per member	Proceedings, annually.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	Thomas Stock, 16 Colville Place, Edinburgh	241	10*s.* 6*d.*	12*s.* 6*d.*	Transactions, annually.
Essex Field Club, 1880	Essex F. C.	William Cole, 7 Knighton Villas, Buckhurst Hill, Essex	360	10*s.* 6*d.*	10*s.* 6*d.*	Essex Naturalist, monthly. [Previous to Jan. 1887, Transactions and Proceedings, irregularly.]
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. B. Murdoch, 18 Bridge Street, Glasgow	200	None	10*s.*	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	D. A. Boyd and R. Broom, 207 Bath Street, Glasgow	257	7*s.* 6*d.*	7*s.* 6*d.*	Proceedings and Transactions, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	John Mayer, 207 Bath Street, Glasgow	729	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts. N. H. Soc.	Public Library, Watford. F. G. Lloyd and C. E. Shelly	265	10*s.*	10*s.*	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	Public Hall, Reigate. A. J. Crosfield	78	—	Members 10*s.*; Subscribers 5*s.*	Proceedings, every two years.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	Thomas Wallace, High School, Inverness	160	None	5*s.*	Transactions, occasionally.
Ireland, Royal Geological Society of, 1831	R. Geol. Soc. Ireland	Prof. W. J. Sollas, F.G.S., Trinity College, Dublin	140	None	1*l.* 1*s.*	Journal, generally annually.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	W. F. Bailey, 35 Molesworth Street, Dublin	190	None	1*l.*	Journal, annually.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	C. J. Billson, M.A., St. John's Lodge, Clarendon Park Road, Leicester	315	None	1*l.* 1*s.*	Report, annually, and Transactions, quarterly.
Liverpool Engineering Society, 1875	Liv'pool E. Soc.	Royal Institution. Thomas L. Miller, 19 Percy Street, Liverpool	160	None	1*l.* 1*s.*	Transactions, annually.
Liverpool Geological Society, 1849	Liv'pool Geol. Soc.	Royal Institution. W. Hewitt, B.Sc., 21 Verulam Street, Liverpool	53	None	1*l.* 1*s.*	Proceedings, annually.

Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc.	Royal Institution. James Birchall, Kirkdale, Liverpool	271	10*s.* 6*d.*	1*l.* 1*s.*	Proceedings, annually.
Liverpool Microscopical Society, 1868	Liv'pool Mic. Soc. . .	Royal Institution. Thomas W. Bruce, 27 Wapping, Liverpool	160	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	W. J. Cain, Woodbourne Square, Douglas, Isle of Man	90	2*s.* 6*d.*	5*s.*	—
Manchester Geographical Society .	Manch. Geog. Soc. .	Eli Sowerbutts, 44 Brown Street, Manchester	Ordinary 400 Associates 35	None	Ordinary 1*l.* 1*s.* Associates 10*s.* 6*d.*	Journal; usually quarterly.
Manchester Geological Society, 1838	Manch. Geol. Soc. .	Mark Stirrup, F.G.S., High Thorn, Bowdon, Cheshire.	215	None	1*l.*	Transactions; nine or ten parts per annum.
Manchester Statistical Society, 1833	Manch. Stat. Soc. . .	Francis E. M. Beardsall and G. H. Pownall, 25 Booth Street, Manchester	185	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1865	Marlb. Coll. N. H. Soc.	The Green, Marlborough. Rev. T. N. Hart Smith (Pres.)	120	1*s.* 6*d.*	3*s.*	Report, annually.
Midland Union of Natural History Societies, 1877	Mid. Union . . .	Thomas H. Waller, 71 Gough Road, Birmingham	2,000	—	—	'Midland Naturalist,' monthly.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst. . .	Neville Hall, Newcastle-on-Tyne. Theo. Wood Bunning	Ordinary 480 Assoc. Memb. 156 Students 69	None	21*s.*, 42*s.*, 63*s.*	Transactions, annually.
North Staffordshire Naturalists' Field Club and Archæological Society, 1865	N. Staff. N. F. C. A. Soc.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	385	5*s.*	5*s.*	Report, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton. N. H. Soc. . .	The Museum, Guildhall Road. H. J. Eunson, F.G.S., 20 St. Giles Street, Northampton	180	None	10*s.*	Journal, quarterly.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst. .	J. Gardner, 3 County Place, Paisley	325	5*s.*	7*s.* 6*d.*	Report, annually.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc. .	E. D. Marquand, Alphington, Exeter, and G. F. Tregelles, Penzance	88	None	10*s.* 6*d.*	Transactions, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci. .	Tay Street, Perth. S. T. Ellison .	320	2*s.* 6*d.*	5*s.* 6*d.*	Proceedings, annually.
Rochester Naturalists' Club, 1878	Rochester N. C. . .	John Hepworth, Union Street, Rochester	105	2*s.* 6*d.*	3*s.* 6*d.*	'Rochester Naturalist,' quarterly.
Royal Scottish Geographical Society, 1884	R. Scot. Geog. Soc. .	80A Princes Street, Edinburgh. A. Silva White	1,102	None	1*l.* 1*s.*	'Scottish Geographical Magazine,' monthly.
South African Philosophical Society, 1877	S. African Phil. Soc.	W. H. Finlay, M.A., Royal Observatory, Cape of Good Hope	Ordinary 70, Corresponding 23	None	2*l.*	Transactions and Proceedings; annually (if possible).
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C. .	Rev. P. B. Brodie, M.A., Rowington Vicarage, Warwick	Limited to 100	2*s.* 6*d.*	5*s.*	Proceedings, annually.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	James W. Davis, Chevinedge, Halifax	250	None	13*s.*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union .	W. Eagle Clarke, Headingley, Leeds, and W. Denison Roebuck, Sunny Bank, Leeds	375 and 1,915 Associates	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.

Index of Papers referring to Local Scientific Investigations published by the above-named Societies during the year ending June 1, 1887.

*** This catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Pub-lished
Billson, C. J.	The Fourth Dimension of Space	Leicester Lit. Phil. Soc.	*Trans.*	II.	11	1887
Blomefield, Rev. L.	Further Results of Meteorological Observations made at the Bath Royal Literary and Scientific Institution	Bath N. H. A. F. C.	*Proc.*	VI.	185	„
Burder, Dr. G. F.	Rainfall at Clifton in 1885	Bristol Nat. Soc.	„	V.	55	1886
Cornish, T.	A remarkable Hailstorm	Penz. N. H. A. Soc.	*Trans.*	II.	272	1887
Cottam, A.	On a Diagram for a Model of the Solar System to Scale	Herts N. H. Soc.	„	IV.	97	„
Eaton, H. S.	Report of the Meteorological Committee on the Temperature and the Rainfall of the Croydon District for the five years 1881–1885	Croydon M. N. H. Soc.	*Proc. and Trans.*	3	76	1886
Eunson, H. J.	Meteorological Observations at Coton Mill, 1886	N'ton. N. H. Soc.	*Journal*	4	222	1887
Evans, F. G.	The Meteorology of 1886	Cardiff Nat. Soc.	*Report and Trans.*	XVIII.	67	„
Graham, Rev. R.	The 'After Glow' or Extraordinary Sunsets of 1883–84	Perths. Soc. N. Sci.	*Proc.*	I.	228	1886
Gray, P.	The Influence of Trees on Climate and Rainfall	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	72	1887
Harvey, Rev. C. W.	Meteorological Observations taken at Throcking, Herts, during the year 1885	Herts N. H. Soc.	*Trans.*	IV.	65	1886
„ „	Report on the Rainfall in Hertfordshire in 1885	„ „	„	„	73	„
Henderson, Rev. A.	Meteorological Observations taken at Coats Observatory	Paisley Phil. Inst.	*Report*	—	—	1887
Hewitt, C. E. B.	Weather Report, July–December, 1886	Marlb. Coll. N. H. Soc.	„	35	122	„
Hopkinson, J.	Meteorological Observations taken at Wansford House, Watford, during the year 1885	Herts N. H. Soc.	*Trans.*	IV.	83	1886
Johnson, R. C.	Note on the New Star in the Nebula of Andromeda	Liv'pool Lit. Phil. Soc.	*Proc.*	XL.	xliv.	„
Jupp, H. B.	Meteorological Observations as regards Temperature, taken at Clifton, 1885	Bristol Nat. Soc.	„	V.	57	„

McLandsborough, J., & A. E. Preston	Meteorology of Bradford	Yorks. Geol. Poly. Soc.	”	IX.	337	1887
M'Lellan, D.	Meteorological Notes for 1885, and Remarks on the State of Vegetation in the Public Parks of Glasgow	Glasgow N. H. Soc.	*Proc. and Trans.*	I.	305	”
Marshall, W. P.	On the Causes of Glacier Motion	Birm. N. H. M. Soc.	*Mid. Naturalist*	X.	41	”
Reynolds, R.	Abnormal Barometrical Disturbances in Yorkshire in 1883–84	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	214	”
Terry, H., and F. Law	Meteorological Reports and Observations	N'ton. N. H. Soc.	*Journal*	4	51, 93, 150, 212	1886
Wells, J. G.	Meteorological Summary for 1886	Burton N. H. Arch. Soc.	*Report*	Eleventh	19	1887
White, H.	Remarks on a further Discharge of Lightning at the West Thornley Colliery, near Tow Law, on Oct. 21, 1886	N. Eng. Inst.	*Trans.*	XXXVI.	47	”

Section B.—CHEMICAL SCIENCE.

Coxon, S. B.	On 'Securité,' a new Blasting Compound	N. Eng. Inst.	*Trans.*	XXXVI.	79	1887
Fitzmaurice, C. H.	The Purification and Softening of Water for Boiler and other purposes	Cornw. Min. Assoc. Inst.	”	1	179	”
Mercier, M.	On Dust in Mines	Manch. Geol. Soc.	”	XIX.	94	”
Sorby, Dr. H. C.	On some remarkable Properties of the Characteristic Constituents of Steel	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	145	”
Woodward, H. A.	Notes on Outbursts of Gas in the Mines at Clifton, Kersley, and Newtown Collieries	Manch. Geol. Soc.	*Trans.*	XIX.	60	”

Section C.—GEOLOGY.

Adamson, S. A.	The Hitchingstone, Keighley Moor	Yorks. Nat. Union	*The Naturalist*	For 1886	333	1886
” ”	Amongst the Yorkshire Oolites	” ”	” ”	For 1887	177	1887
Adamson, S. A., and A. Harker	Bibliography of Geology for the North of England	” ”	” ”	For 1886	349	1886
Andrews, W.	On a new Discovery of Cambrian Rocks between Chilvers Coton and Burton Hastings	Warw. N. A. F. C.	*Proc.*	”	31	1887
Anonymous	Colliery Explosions and the Weather of 1885	Yorks. Geol. Poly. Soc.	”	IX.	248	”
Bates, E. F., and L. Hodges	Notes on a recent Exposure of the Lower Lias and Rhætics in the Spinney Hills, Leicester	Leicester Lit. Phil. Soc.	*Trans.*	I.	22	1886

Section C.—GEOLOGY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Beasley, H. C.	A Section of the Upper Keuper Beds recently exposed at Oxton	Liv'pool Geol. Soc.	*Proc.*	V.	134	1886
Bell, D.	Notes on the Geology of Oban	Glasgow Geol. Soc.	*Trans.*	VIII.	116	„
Bell, R. W.	The Pliocene Beds of St. Erth	Cornw. R. Geol. Soc.	*Report and Trans.*	XI.	45	1887
Bird, C.	The Chalk, Part II.	Rochester N. C.	*Roch. Naturalist*	14	233	1886
Bragge, G. S.	The Geology of the South Derbyshire and East Leicestershire Coalfields	Chesterf. Mid. Count. Inst.	*Trans.*	XV.	198	„
„ „	Sections of Coal-measures in East Derbyshire, South Derbyshire, and Leicestershire	„ „	„	„	327	1887
Brett, A. T.	Section at the Sewage Farm, Watford Fields	Herts N. H. Soc.	„	IV.	117	„
Brodie, Rev. P. B.	On Two Rhætic Sections in Warwickshire	Warw. N. A. F. C.	*Proc.*	For 1886	26	„
„ „	Further and Concluding Notes on the Deep Boring at Richmond, Surrey, and on another at Chatham and other places in Kent	„ „	„	„	33	„
Burnett, R. T.	The Question of the Pre-Atlantic Land	Manch. Geol. Soc.	*Trans.*	XIX.	79	„
Coutts, J.	Notice of the late Mr. Andrew Patton, East Kilbride, cor. mem.	Glasgow Geol. Soc.	„	VIII.	171	1886
Craig, R.	On the Upper Limestones of North Ayrshire, as found in the District around Dalry, and elsewhere	„ „	„	„	28	„
„ „	List of Fossils in the Upper Limestones of North Ayrshire	„ „	„	„	36	„
Crick, W. D.	Note on some Foraminifera from the Oxford Clay at Keyston, near Thrapston	N'ton. N. H. Soc.	*Journal*	4	233	1887
Dairon, J.	The Rocks of the Moffat District and their Fossil Remains	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	75	„
Davis, J. W.	On some Remains of Fossil Trees found in the Lower Coal-measures at Clayton, near Halifax	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	253	„
„ „	On the Exploration of the Raygill Fissure in Lothersdale	„ „	„	„	280	„
Dawkins, Professor Boyd	On the Formation of Agates	Manch. Geol. Soc	*Trans.*	XVIII.	525	1886
„ „	On the Geography of Britain in the Carboniferous Period	„ „	„	XIX.	37	1887
Dowker, G.	The Water Supply of East Kent, in connection with Natural Springs and Deep Wells	E. Kent N. H. Soc.	„	2	41	1886

Eunson, H. J.	Notes on the Deep Boring at Orton, near Kettering, Northamptonshire	N'ton. N. H. Soc.	*Journal*	4	57	1886
" "	List of Works on the Geology, Mineralogy, and Palæontology of Northamptonshire	" "	"	"	178	"
Fisher, Rev. O.	On the Subsidence at Lexden, near Colchester, in 1862	Essex F. C.	*Essex Naturalist*	I.	39	1887
Grieve, Dr. J.	On the Pagoda Stone of the Chinese (*Orthoceras* sp.)	Glasgow N. H. Soc.	*Proc. and Trans.*	I.	394	"
Hewitt, W.	Notes on the Topography of Liverpool	Liv'pool Geol. Soc.	*Proc.*	V.	145	1886
Hey, Rev. W. C.	Flamborough Head	Yorks. Nat. Union	*The Naturalist*	For 1886	161	"
Higgins, Rev. H. H.	Fossil Insects from the Coal-measures, Ravenhead, St. Helens, 1870	Liv'pool Lit. Phil. Soc.	*Proc.*	XL.	liv.	"
Holmes, T. V.	On the Subsidence at Lexden, near Colchester, in 1862	Essex F. C.	*Essex Naturalist*	I.	1	1887
" "	Geological Section at High Beach, Epping Forest	" "	" "	"	107	"
Hopkinson, J.	Section at the St. Albans New Waterworks	Herts N. H. Soc.	*Trans.*	IV.	117	"
Hunter, Dr. J. R. S.	The Old Red Sandstone of Lanarkshire, with Notes on Volcanic Action during Old Red and Carboniferous Times	Glasgow Geol. Soc.	"	VII.	161	1886
" "	Notes on the Discovery of a Fossil Scorpion (*Palæophonus caledonicus*) in the Silurian Strata of Logan Water	" "	"	"	169	"
Jeffs, O. W.	Note on the Occurrence of Copper in the Keuper Sandstone at the Peckforton Hills, Cheshire	Liv'pool Geol. Soc.	*Proc.*	V.	139	"
Jolly, W.	The Parallel Roads of Lochaber; the Problem, its Conditions and Solutions	Glasgow Geol. Soc.	*Trans.*	VIII.	40	"
"	The Joint Excursion of the Edinburgh and Glasgow Geological Societies to Ben Nevis and the Parallel Roads of Lochaber, in July 1885	" "	"	"	72	"
Jones, Prof. T. R., and J. W. Kirkby	On Carboniferous Ostracoda from the Gayton Boring, Northamptonshire	N'ton. N. H. Soc.	*Journal*	4	98	"
Kendall, J. D.	The Iron Ores of the English Secondary Rocks.	N. Eng. Inst.	*Trans.*	XXXV.	105	"
Kendall, P. F.	The Carboniferous Volcanoes of Great Britain	Manch. Geol. Soc.	"	XIX.	133	1887
Kidston, R.	Notes on some Fossil Plants collected by Mr. R. Dunlop, Airdrie, from the Lanarkshire Coalfield	Glasgow Geol. Soc.	"	VIII.	47	1886
Kinahan, G. H.	On the extent of the Carboniferous Sea as regards Ireland	Manch. Geol. Soc.	"	XIX.	114	1887

Section C.—GEOLOGY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Pub-lished
Kinahan, G. H.	On Marsh (Natural) Gas	Manch. Geol. Soc.	*Trans.*	XIX.	121	1887
Lovett, E.	Notes on the Glacial Deposits and other interesting Geological Features of North Yorkshire	Croydon M. N. H. Club	*Proc. and Trans.*	3	37	1886
Mello, Rev. J. M.	On the Microscopical Structure of Rocks	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	151	1887
Mitchell, J.	On Explosives used in Mining	" "	"	"	147	"
Moore, Dr. C. A.	The Influence of the Geological Features of a District on the Health of its Inhabitants	Leicester Lit. Phil. Soc.	*Trans.*	II.	20	"
Morgan, Prof. C. Lloyd	Contributions to the Geology of the Avon Basin: Part III. The Portbury and Clapton District; Part IV. On the Geology of Portishead	Bristol Nat. Soc.	*Proc.*	V.	1	1886
Morton, G. H.	The Carboniferous Limestone and Cefn-y-Fedw Sandstone of Flintshire	Liv'pool Geol. Soc.	"	V.	169	"
Parsons, Dr. H. F.	Waterfall on Kinderscout, Derbyshire	Yorks. Nat. Union	*The Naturalist*	For 1886	310	"
Paul, J. D.	Shearsby, the Cheltenham of Leicestershire	Leicester Lit. Phil. Soc.	*Trans.*	III.	9	1887
Postlethwaite, J.	The Mineral Springs near Keswick	Cumb. West. Assoc.	"	XI.	142	1886
Reade, T. M.	The North Atlantic as a Geological Basin	Liv'pool Geol. Soc.	*Proc.*	V.	114	"
" "	Notes on a Bed of Freshwater Shells and a Chipped Flint lately found at the Alt Mouth	" "	"	"	137	"
" "	Boulders wedged in the Falls of the Cynfael	" "	"	"	155	"
" "	On a Section of the Trias at Vyrnwy Street, Everton, displaying Evidence of Lateral Pressure	" "	"	"	158	"
Ricketts, Dr. C.	The Occurrence of Bitumen in the Palæozoic Rocks of Shropshire	" "	"	"	131	"
" "	Impressions of Footprints and Plants from the Trias at Oxton Heath	" "	"	"	168	"
Rudler, F. W.	On the Application of the Microscope to the Study of Rocks	Croydon M. N. H. Club	*Proc. and Trans*	3	13	"
Shelly, C. E.	Earthquake in the West of England felt at Hertford	Herts N. H. Soc.	*Trans.*	IV.	116	1887
Shipman, J.	Some Traces of an Ancient (Keuper) Beach at Castle Donington	Yorks. Nat. Union	*The Naturalist*	For 1887	33	"
Smyth, Sir W. W.	Remarks on the Geology of St. Michael's Mount	Cornw. Min. Assoc. Inst.	*Trans.*	1	132	"
Stocks, H. B.	On a Concretion called Acrespire	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	149	"

Tate, A. N.	The Origin of Petroleum and other Natural Hydrocarbons	Liv'pool Geol. Soc.	"	V.	160	1886
Thompson, B.	The Middle Lias of Northamptonshire economically considered	N'ton. N. H. Soc.	*Journal*	4	167	"
" "	The Upper Lias of Northamptonshire, Part V.	" "	"	"	215	1887
Tuckwell, Rev. W.	The Erratics of Leicestershire and Warwickshire	" "	"	"	145	1886
Tute, Rev. J. S.	On the Cayton Gill Beds	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	265	1887
Various	Geological Report	Marlb. Coll. N. H. Soc.	*Report*	35	100	"
Verini, W.	Section at the Well and Boring made at the Colne Valley Waterworks, Watford, in 1885	Herts N. H. Soc.	*Trans.*	IV.	116	"
Vine, G. R.	Jurassic Polyzoa in the Neighbourhood of Northampton	N'ton. N. H. Soc.	*Journal*	4	202	"
" "	Notes on the Palæontology of the Wenlock Shales of Shropshire	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	224	"
Waller, T. A.	Presidential Address	Birm. N. H. M. Soc.	*Mid. Naturalist*	IX.	11, 43	1886
Ward, T.	On the Subsidences in the Salt District of Cheshire: their History and Cause	Manch. Geol. Soc.	*Trans.*	XIX.	152	"
Watts, W.	Geological Sketches at Piethorn and Denshaw	" "	"	"	47	"
Whitaker, W.	Some Essex Well Sections	Essex F. C.	*Trans.*	IV.	149	"
" "	Some Surrey Wells and their Teachings; with Sections of Wells and Deep Borings in the Surrey part of the London Basin	Croydon M. N. H. Club	*Proc. and Trans.*	3	43	"
White, J.	A Glimpse of Skye; with Remarks on Volcanic Action	Glasgow Geol. Soc.	*Trans.*	VIII.	105	"
"	Notes on Tarbert, Argyllshire	" "	"	"	111	"
Wilson, E.	The Bone Cave or Fissure of Durdham Down	Bristol Nat. Soc.	*Proc.*	V.	31	"
Woodward, H. B.	Notes on the Geology of Brent Knoll, in Somersetshire	Bath N. H. A. F. C.	"	VI.	125	1887
" "	Notes on the Ham Hill Stone	" "	"	"	182	"
Worth, R. N.	On an Unmapped Exposure of Serpentinous Rock in Whitsand Bay	Cornw. R. Geol. Soc.	*Report and Trans.*	XI.	51	"
Young, J.	Notes on Cone-in-Cone Structure	Glasgow Geol. Soc.	*Trans.*	VIII.	1	1886
"	Notice of the late Dr. Thomas Davidson, F.R.S., F.G.S., hon. mem.	" "	"	"	138	"
"	Notes on the Carboniferous *Brachiopoda*, with Revised list of the Genera and Species	" "	"	"	143	"
"	Notice of the late Mr. James Coutts	" "	"	"	177	"
Young, J., and D. C. Glen	Notes on the Cathkin 'Osmund Stone,' a Volcanic Tuff	" "	"	"	134	"

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Allen, Rev. F. H.	Micro-Zoology and Botany of Askern	Yorks. Nat. Union	*The Naturalist*	For 1887	70	1887
Angus, W. C.	Ornithological Notes	Glasgow N. H. Soc.	*Proc. and Trans.*	I.	379	"
Aplin, O. V.	Ornithological Notes from Lincolnshire and Norfolk	Yorks. Nat. Union	*The Naturalist*	For 1887	79	"
Atmore, E. A.	Notes on the Lepidoptera of West Cornwall, with a further addition of species to the recorded Fauna	Penz. N. H. A. Soc.	*Trans.*	II.	266	"
Backhouse, J., jun.	A Yorkshire Specimen of *Sturnus unicolor*, and other Uncommon Birds, in a York Collection	Yorks. Nat. Union	*The Naturalist*	For 1886	307	1886
Bagnall, J. E.	Notes on the Anker Valley and its Flora	Birm. N. H. M. Soc.	*Mid. Naturalist*	IX.	54, 69, 89	"
"	A Half-day's Ramble in the Arrow District	" "	" "	"	117	"
Baker, J. G.	Botany of the Cumberland Border Marches	Yorks. Nat. Union	*The Naturalist*	For 1886	325	"
Beeby, W. H.	A new Flora of Surrey	Croydon M. N. H. Club	*Proc. and Trans.*	3	1	"
"	On *Sparganium neglectum*, sp. nov., and other new Surrey Plants	" "	" "	"	33	"
"	On some recent Additions to the Flora of Surrey	" "	" "	"	40	"
Bell, Prof. F. J.	Mammalia	Marlb. Coll. N. H. Soc.	*Report*	35	70	1887
Bennett, A.	The Broads and Fens of East Anglia	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	72	"
"	Recent Additions to the British Flora	" "	" "	"	148	"
Bennett, A. W.	Plant-life in our Ponds and Ditches	Croydon M. N. H. Club	*Proc. and Trans.*	3	39	1886
Binstead, C. H.	Some Rare Mosses in Westmorland	Yorks. Nat. Union	*The Naturalist*	For 1887	65	1887
Bolton, T.	Micro-organisms in a swampy ditch in Sutton Park	Birm. N. H. M. Soc.	*Mid. Naturalist*	IX.	173	1886
Bossey, Dr F.	Atmospheric Dust as related to Fermentation, &c.	Holmesdale N. H. C.	*Proc.*	For 1884–85	19	"
Boulger, Prof. G. S.	The Life and Work of John Ray, and their relation to the Progress of Science	Essex F. C.	*Trans.*	IV.	171	"
Boyden, Rev. H.	Notes on the River Rea and the Flora of the Rea Valley	Birm. N. H. M. Soc.	*Mid. Naturalist*	IX.	150	"
Brett, A. T.	Notes on Herts Botany and Zoology	Herts N. H. Soc.	*Trans.*	IV.	118	1887
Brown, N. E.	The Development of Starch Granules	Holmesdale N. H. C.	*Proc.*	For 1884–85	17	1886
" "	Continuity of Protoplasm	" "	"	"	"	"
Brown, T.	A List of the Birds of Tynron Parish	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	113	1887

Browne, M.	On the Occurrence of a Mammal hitherto unknown as inhabiting Leicestershire	Leicester Lit. Phil. Soc.	*Trans.*	I.	27	1886
,,	Dates of Arrival of Summer Birds of Passage in Leicestershire, from 1843 to 1855, and from 1877 to 1886	,, ,,	,,	,,	28	,,
Bucknall, C.	The Fungi of the Bristol District (Part IX.)	Bristol Nat. Soc.	*Proc.*	V.	46	,,
Cameron, P.	Biological Notes	Glasgow N. H. Soc.	*Proc. and Trans.*	I.	295	1887
Carter, T.	Marfield Pond, Masham, and its Bird Life	Yorks. Nat. Union	*The Naturalist*	For 1886	231	1886
Cash, J.	The Early Botanical Work of the late William Wilson	,, ,,	,, ,,	For 1887	181	1887
Chaney, W.	The Macro-Lepidoptera of the Rochester and Chatham District	Rochester N. C.	*Roch. Naturalist*	13	217	1886
Chapman, A. C.	Notes on the Cuckoo	Yorks. Nat. Union	*The Naturalist*	For 1886	237	,,
,, ,,	The Pied Flycatcher in Northumberland	,, ,,	,, ,,	,,	341	,,
Chapman, E.	List of Wensleydale Birds	,, ,,	,, ,,	,,	183	,,
Chase, R. W.	Presidential Address	Birm. N. H. M. Soc.	*Mid. Naturalist*	X.	1, 29, 114, 142	,,
Clarke, J.	Notes on the Saffron Plant (*Crocus sativus, L.*) in connection with the name of the Town of Saffron Walden	Essex F. C.	*Essex Naturalist*	I.	9	1887
Clarke, W. E., W. D. Roebuck, and W. Storey	Upper Nidderdale and its Fauna	Yorks. Nat. Union	*The Naturalist*	For 1886	193	1886
Coles, F. R.	Remarks on the recent Additions to the Flora of Dumfriesshire and Galloway	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	47	1887
,, ,,	A Leaflet from the Book of Nature	,, ,, ,,	,, ,,	,,	87	,,
,, ,,	A List of Kirkcudbright Mollusks	,, ,, ,,	,, ,,	,,	103	,,
Cooper, H. R.	Wild Birds: their Structure and Habits	Marlb. Coll. N. H. Soc.	*Report*	35	51	,,
Cordeaux, J.	The Birds of the Lincolnshire Fens and Wolds in 1612	Yorks. Nat. Union	*The Naturalist*	For 1886	363	1886
,, ,,	Some Footprints in the Snow	,, ,,	,, ,,	For 1887	72	1887
Dampier, H. L.	Hedge Fruit and the Berries of the Chalk	Rochester N. C.	*Roch. Naturalist*	15	249	,,
Daltry, Rev. T. W.	Entomological Report, March 1887	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1886	10	,,
Davidson, Dr. A.	Notes on the Flora of Upper Nithsdale, and Additions to the Flora of Dumfriesshire	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	50	,,
,, ,,	The Botany of the Sanquhar District	,, ,,	,, ,,	,,	109	,,
Dixon, H. N.	Phenological Observations for 1885	N'ton. N. H. Soc.	*Journal*	4	54	1886
,, ,,	Second Supplementary List of Northamptonshire Mosses	,, ,,	,,	,,	106	,,
Druce, G. C.	The Flora of Northamptonshire	,, ,,	,,	,,	87, 116, 173	,,

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Editors	Bibliography of Botanical Papers for the North of England	Yorks. Nat. Union	*The Naturalist*	For 1886	174	1886
"	Bibliography of Mammalia for the North of England	" "	" "	"	239	"
"	Bibliography of Birds for the North of England	" "	" "	"	260	"
Ellis, J. W.	Liverpool District Coleoptera	" "	" "	"	164, 245	"
" "	Lepidopterous Fauna of Lancashire and Cheshire	" "	" "	For 1886	285	"
				For 1887	93	1887
English, J. L.	Entomological Notes from an old Pocket Book	Essex F. C.	*Essex Naturalist*	I.	109	"
Ewing, P.	Notes on some Alpine Plants from Forfarshire and Aberdeenshire	Glasgow N. H. Soc.	*Proc. and Trans.*	I.	286	"
Farquharson, Mrs.	Notes on Mosses of the North of Scotland	E. Scot. Union	*Proc.*	—	66	1886
Fielding, Rev. C. H.	Estuarine and River Flora of Kent	Rochester N. C.	*Roch. Naturalist*	16	271	1887
Fingland, J.	Botanical Field Notes for 1885	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	145	"
Fortune, R.	Ornithological Notes from Northumberland and Durham during 1885	Yorks. Nat. Union	*The Naturalist*	For 1887	132	"
Gilbert, H. W.	How and why Animals differ	Holmesdale N. H. C.	*Proc.*	For 1884-85	33	1886
Goodchild, J. G.	Hawks and their Allies, with Notes on Hawking	Croydon M. N. H. Club	*Proc. and Trans.*	3	30	"
Gough, Mrs. F.	Sea Anemones	Penz. N. H. A. Soc.	*Trans.*	II.	275	1887
Griffiths, G. C.	*Cicada septemdecim*	Bristol Nat. Soc.	*Proc.*	V.	84	1886
Grove, W. B.	Fungus Hunting in Spring	Birm. N. H. M. Soc.	*Mid. Naturalist*	IX.	127, 164	"
" "	The *Boleti* of the Birmingham District	" "	" "	"	264	"
Gurney, J. H., jun.	Little Gulls at Flamborough Head	Yorks. Nat. Union	*The Naturalist*	For 1887	22	1887
Harting, J. E.	The Deer of Epping Forest	Essex F. C.	*Essex Naturalist*	I.	46	"
Hastings, W.	Notes on Local Ornithology	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	45	"
" "	" " " for 1885	" " "	" "	"	121	"
Hay, Col. H. M. D.	Report on the Ornithology of the East of Scotland, from Fife to Aberdeenshire inclusive	E. Scot. Union	*Proc.*	—	25	1886
Henderson, Prof. J. R.	The Decapod and Schizopod Crustacea of the Firth of Clyde	Glasgow N. H. Soc.	*Proc. and Trans.*	1.	315	1887
Herdman, Prof., and others	First Report upon the Fauna of Liverpool Bay and the Neighbouring Seas	Liv'pool Lit. Phil. Soc.	*Proc.*	XL.	Appendix	1886
Hey, Rev. W. C.	Notes on Decapodous Crustacea found at Redcar	Yorks. Nat. Union	*The Naturalist*	For 1887	85	1887
Hick, T.	Strasburger on Foreign Pollination	" "	" "	For 1886	369	1886

„ „	The Botany of the Solway Shore	„ „	„	„	114	„
Hopkinson, J.	Report on Phenological Phenomena observed in Hertfordshire during the year 1885	Herts N. H. Soc.	„	IV.	93	„
Howden, Dr. J. C.	Report on the Fishes of the North-East of Scotland	E. Scot. Union	*Proc.*	—	51	„
Hudson, Dr.	Strange Captives of the Tow Net	Marlb. Coll. N. H. Soc.	*Report*	35	78	1887
Jackson, J. A.	Notes on the Black-headed Gull near Garstang	Yorks. Nat. Union	*The Naturalist*	For 1887	129	„
Kew, H. W.	A Half-day's Ramble on the Lincolnshire Coast	„ „	„ „	For 1886	171	1886
„ „	Spiders obtained in North Lincolnshire, 1886	„ „	„ „	For 1887	55	1887
King, J. J.	Notes on some Trichoptera from the Stewartry	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	57	„
King, J. J. F. X.	Notes on the Neuroptera of Rothiemurchus and Kingussie	Glasgow N. H. Soc.	*Proc. and Trans.*	I.	354	„
Lilford, Lord	Notes on the Birds of Northamptonshire	N'ton. N. H. Soc.	*Journal*	4	191	„
„ „	Notes on the Ornithology of Northamptonshire	„ „	„	„	227	„
Littleboy, J. E.	Notes on Birds observed in Hertfordshire during the year 1885	Herts N. H. Soc.	*Trans.*	IV.	53	1886
Lofthouse, R.	The River Tees: its Marshes and their Fauna	Yorks. Nat. Union	*The Naturalist*	For 1887	1	1887
Lovett, E.	The Edible Mollusca or Shell-fish of the British Islands	Croydon M. N. H. Club	*Proc. and Trans.*	3	11	1886
M'Andrew, J.	A Day on Ben Lawers	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	108	1887
M'Andrew, J.	On some forms of *Sphagna* found in the Glenkens, Kircudbrightshire	Glasgow N. H. Soc.	„ „	I.	366	„
McDakin, Capt.	*Bos longifrons*	E. Kent N. H. Soc.	*Trans.*	2	53	1886
Macfadzean, R. W.	The Arctic Shell-beds of the Clyde	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	93	1887
Macpherson, Rev. H. A.	The Habits of the greater Horse-shoe Bat	Yorks. Nat. Union	*The Naturalist*	For 1886	337	1886
Macpherson, Rev. H. A., and W. Duckworth	Nesting of the Shoveller in Cumberland	„ „	„ „	„	235	„
Marquand, E. D.	Dartmoor	Penz. N. H. A. Soc.	*Trans.*	II.	249	1887
Marshall, W. P.	An Excursion to Tenby	Birm. N. H. M. Soc.	*Mid. Naturalist*	X.	7	„
Martindale, J. A.	New British Lichens	Yorks. Nat. Union	*The Naturalist*	For 1886	279	1886
„ „	The Lichens of Westmoreland	„ „	„ „	„	317	„
„ „	„ „ „	„ „	„ „	For 1887	47	1887
Masefield, J. R. B.	Zoological Report, March 1887	N. Staff. N. F. C. A. Soc.	*Report*	For 1886	12	„
„ „	The Wild Cattle of Chartley Park, Staffordshire	„ „	„	„	32	„
Mott, F. T.	The Campanulas of Leicestershire	Leicester Lit. Phil. Soc.	„	I.	24	1886
„ „	The Wild Geraniums of Leicestershire	„ „	„	III.	14	1887
Nelson, T. H.	Ornithological Notes from Redcar in 1886	Yorks. Nat. Union	*The Naturalist*	For 1887	81	„
„ „	A Naturalist's Ramble on the Farne Islands	„ „	„ „	„	116	„

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Plant, J.	The Land and Freshwater Mollusca indigenous to Leicestershire, 1850	Leicester Lit. Phil. Soc.	*Trans.*	II.	24	1887
Pollard, H.	Land and Freshwater Shells in the neighbourhood of Whitby	Yorks. Nat. Union	*The Naturalist*	For 1887	134	„
Porritt, G. T.	*Tortrix transitana*, *Spilonota rosæcolana*, and *Depressaria weirella* in Yorkshire	„ „	„ „	„	21	„
„ „	Lepidoptera, &c., on the North-east Coast of Yorkshire in August 1886	„ „	„ „	„	67	„
Prodham, H.	An unrecorded Occurrence of the Golden Eagle in Yorkshire	„ „	„ „	„	84	„
Pryor, R. A.	Notes on some Hertfordshire Carices	Herts N. H. Soc.	*Trans.*	IV.	121	„
Quilter, H. E.	The Metamorphoses of *Galeruca nymphea*, Lin.	Leicester Lit. Phil. Soc.	„	III.	17	„
Reed, J. T. T.	Local Specimens of rare Birds in the Museum at Newcastle-on-Tyne	Yorks. Nat. Union	*The Naturalist*	For 1887	75	„
Reid, A. S.	Notes on the Intelligence of a young Raven	E. Kent N. H. Soc.	*Trans.*	2	63	1886
Reid, J.	A Sanitary Law exemplified in Vegetable Life	„ „	„	„	56	„
„	Some Physical Conditions of Smut in Wheat	„ „	„	„	68	„
„	Malformed Fruit of a Blackthorn or Sloe Tree	„ „	„	„	70	„
Roberts, G.	Mollusca of Wressle and Neighbourhood	Yorks. Nat. Union	*The Naturalist*	For 1886	311	„
„ „	Notes on Varieties of *Bythinia tentaculata*	„ „	„ „	For 1887	19	1887
Robertson, D.	Jottings from my Note Book	Glasgow N. H. Soc.	*Proc. and Trans.*	I.	290	„
Roebuck, W. D., and J. W. Taylor	Bibliography of Works and Papers relating to the Mollusca of Northamptonshire	N'ton. N. H. Soc.	*Journal*	4	108	1886
Rosseter, T. B.	On *Trichidona* as an Endoparasite	E. Kent N. H. Soc.	*Trans.*	2	72	„
Sarjeant, W. L.	Pond Life	Croydon M. N. H. Club	*Proc. and Trans.*	3	5	„
Saunders, S.	On the Dental Apparatus of the Higher Mollusca	E. Kent N. H. Soc.	*Trans.*	2	58	„
Scott, D. H.	Some Facts about the Reproduction of Seaweeds	Penz. N. H. A. Soc.	„	II.	237	1887
Scott, T.	Notes on the Land and Freshwater Mollusca of Greenock and surrounding District	Glasgow N. H. Soc.	*Proc. and Trans.*	I.	279	„
„	Natural History Notes from Tarbert	„ „	„ „	„	369	„
Scriven, R. G.	The Age of Trees	N'ton. N. H. Soc.	*Journal*	4	113, 163	1886
Selby, Miss Ada	Flowering Plants observed in Hertfordshire during the years 1884 and 1885	Herts N. H. Soc.	*Trans.*	IV.	118	1887
Shaw, J.	Dates of First Blossoming of Plants in Tynron	Dum. Gal. N. H. Soc	*Trans. and Proc.*	4	56	„

Shenstone, J. C.	Report on the Flowering Plants growing in the Neighbourhood of Colchester	Essex F. C.	*Essex Naturalist*	I.	22	„
Silvester, F. W.	Report on Insects observed in Hertfordshire during the year 1885	Herts N. H. Soc.	*Trans.*	IV.	49	1886
Smith, G. M.	Sleep and Dreams	Bristol Nat. Soc.	*Proc.*	V.	62	„
Somerville, J. E.	*Gonometa postica* (Walker)	Glasgow N. H. Soc.	*Proc. and Trans.*	I.	312	1887
Southwell, T.	*Balænoptera musculus* at Skegness	Yorks. Nat. Union	*The Naturalist*	For 1887	139	„
Standen, R.	Lancashire Land and Freshwater Mollusca	„ „	„ „	„	155	„
Stradling, A.	Reptiles recently observed near Watford	Herts N. H. Soc.	*Trans.*	IV.	119	„
Thompson, F. C.	The Anatomy of the Freshwater Mussel	N'ton. N. H. Soc.	*Journal*	4	82	1886
Thornewill, Rev. C. F., J. G. Wells, and J. E. Nowers	Calendar of Nature, 1886	Burton N. H. Arch. Soc.	*Report*	Eleventh	22	1887
Trail, Prof. J. W. H.	Presidential Address on the Work of the Union	E. Scot. Union	*Proc.*	—	13	1886
„ „	Report for 1886 on the Fungi of the East of Scotland	„ „	„	—	69	„
Trotter, Dr. De B.	The Fossil Diatoms of the Tay Basin	Perths. Soc. Nat. Sci.	„	I.	223	„
Tyndall, W. H.	The Elm Tree	Holmesdale N. H. C.	„	For 1884-85	10	„
„ „	Mahogany: Where grown; how obtained; its quality and uses	„ „	„	„	66	„
Various	Botanical Report	Marlb. Coll. N. H. Soc.	*Report*	35	82	1887
„	Entomological Report	„ „	„	„	95	„
„	Ornithological Report	„ „	„	„	104	„
Vice, W. A.	Notes on the British *Bibonidæ*	Leicester Lit. Phil. Soc.	*Trans.*	II.	34	„
„ „	The Pharyngeal Teeth of the Chub and Roach	„ „ „	„	III.	21	„
Vine, G. R.	Notes on the Polyzoa of the Wenlock Shales, &c.	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	179	„
Wake, Sir H.	Instinct and Reason	N'ton. N. H. Soc.	*Journal*	4	153	1886
Watson, J.	Notes on the Eagles of the Lake District	Yorks. Nat. Union	*The Naturalist*	For 1886	343	„
„	The Extinct Animals of the Lake District	„ „	„ „	For 1887	39	1887
White, Dr. F. B.	Report of Excursion to Braemar	E. Scot. Union	*Proc.*	—	7	1886
„ „	Reports of Excursions near Aberdeen	„ „	„	—	9	„
„ „	Opening Address	Perths. Soc. Nat. Sci.	„	I.	220	„
„ „	Presidential Address	„ „	„	„	259	„
White, Dr. F. B., Prof. J. Geikie, J. Coates, S. T. Ellison, and H. Coates	A Series of Papers on the Natural History of Kinmull Hill	„ „	„	„	244	„
White, J. W.	Flora of the Bristol Coalfield (Part VI.)	Bristol Nat. Soc.	„	V.	211	„

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Wilkinson, W. H.	A Ramble amongst the Lichens in the Island of Bute	Birm. N. H. M. Soc.	*Mid. Naturalist*	X.	81	1887
Wilson, T.	Hymenoptera captured near York in 1883 and 1884	Yorks. Nat. Union	*The Naturalist*	For 1886	257	1886
Wood, Rev. J. G.	Pond and Stream	Marlb. Coll. N. H. Soc.	*Report*	35	80	1887

Section E.—GEOGRAPHY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Pub-lished
Brown, R.	The Ocean and its Currents	Perths. Soc. Nat. Sci.	*Proc.*	I.	267	1886
Cadell, H. M.	The Dumbartonshire Highlands	R. Scot. Geog. Soc.	*Magazine*	II.	337	,,
Cardwell, J. J.	Map-drawing and the Teaching of Geography	Manch. Geog. Soc.	*Journal*	2	337	,,
Casartelli, Rev. L. C.	The Teaching of Commercial Geography	,, ,,	,,	,,	328	,,
Cole, W.	John Norden's Map of Essex	Essex F. C.	*Essex Naturalist*	I.	41	1887
Editorial	The Geographical Exhibition and Geographical Education	R. Scot. Geog. Soc.	*Magazine*	II.	420	1886
,,	Early Scottish Geography	,, ,,	,,	III.	87	1887
Hindshaw, R. C.	Models in Elementary Teaching	Manch. Geog. Soc.	*Journal*	2	233	1886
Jolly, W.	On Realistic and Dramatic Methods in teaching Geography	R. Scot. Geog. Soc.	*Magazine*	III.	127, 184	,,
Keltie, J. S.	Geographical Education and Appliances on the Continent	Manch. Geog. Soc.	*Journal*	2	241	,,
Laurie, Prof.	Method—applied to the teaching of Geography in the School	R. Scot. Geog. Soc.	*Magazine*	II.	449	,,
Mill, Dr. H. R.	Physical Exploration of the Firth of Clyde	,, ,,	,,	,,	347	,,
,, ,,	Configuration of the Clyde Sea-area	,, ,,	,,	III.	15	1887
Murray, Dr. J.	The Physical and Biological Conditions of the Seas and Estuaries about North Britain	,, ,,	,,	II.	354	1886
Wilkinson, Capt. H. S.	The War Game	Manch. Geog. Soc.	*Journal*	2	199	,,
,, ,,	Cartography; or, How to Read a Map	,, ,,	,,	,,	322	,,
Yeats, Dr. J.	The Relations between Commercial History and Geography	,, ,,	,,	,,	181	,,

Section F.—Economic Science and Statistics.

Brown, M. W. (translated by)	Regulations for the Management of Fiery Mines in Prussia	N. Eng. Inst.	*Trans.*	XXXV.	167	1886
Fogg, W.	Objections to Free Trade answered	Manch. Stat. Soc.	"	For 1886-88	25	1887
Kelly, W.	The Records of the Corporation of the Borough of Leicester	Leicester Lit. Phil. Soc.	"	I.	13	1886
Macleod, H. D.	On the Modern Science of Economics	Manch. Stat. Soc.	"	For 1886-88	73	1887
Moxon, T. B.	The Basis of Social Prosperity	" "	"	"	1	1886
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Robinson, G. E.	The Chartered Liberties of Cardiff	Cardiff Nat. Soc.	*Report and Trans.*	XVIII.	17	"
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Section G.—Mechanical Science.

Beringer, J. J.	The Technical Education of Miners	Cornw. Min. Assoc. Inst.	*Trans.*	1	164	1887
Daglish, J.	Presidential Address	N. Eng. Inst.	"	XXXV.	223	1886
Dumas, E. L.	Cuvelier's Lock for Safety Lamps	" "	"	XXXVI.	51	1887
Duxbury, W.	The 'Argus' Safety Lamp	Manch. Geol. Soc.	"	XIX.	191	"
Fisher, H.	The Automatic Exhaust Steam-injector, and its Applications to Boiler Feeding and Feed-water Heating	Chesterf. Mid. Count. Inst.	"	XIV.	291	1886
Hall, H.	A new Safety Lamp	Manch. Geol. Soc.	"	XIX.	101	1887
Kirkland, T., and T. Barnett	Kirkland and Barnett's Apparatus for Preventing Overwinding in Collieries	Chesterf. Mid. Count. Inst.	"	XV.	321	"
Lewis, Sir W. T., and A. H. Maurice	A Fire-damp Indicator	N. Eng. Inst.	"	XXXVI.	73	"
Liddell, J. R., and J. H. Merivale	Transmission of Power by Steam	" "	"	XXXV.	159	1886
Mansergh, J.	Burton-on-Trent Sewage Disposal Works, Description of Pumping Station, &c.	Chesterf. Mid. Count. Inst.	"	XV.	215	"

Section G.—MECHANICAL SCIENCE (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Merivale, Prof. J. H.	Transmission of Power by Steam	N. Eng. Inst.	*Trans.*	XXXVI.	13	1887
Smith, G. E.	Schanschieff's Miner's Electric Lamp actuated by a new Single-liquid Battery	Chesterf. Mid. Count. Inst.	"	XV.	86	1886
Steavenson, A. L.	On the System of working Ironstone at Lumpsey Mines by Hydraulic Drills	N. Eng. Inst.	"	XXXVI.	67	1887
Stirrup, M.	The Cambessédès Miners' Safety Lamp	Manch. Geol. Soc.	"	XIX.	198	"
Stokes, A. H.	Notes upon the Report of the Royal Commission on Accidents in Mines	Chesterf. Mid. Count. Inst.	"	XV.	93	1886
"	Notes upon Safety Lamp Experiments	" "	"	"	251	"
Swan, J. W.	An improved Electric Safety Lamp for Miners	N. Eng. Inst.	"	XXXVI.	3	1887

Section H.—ANTHROPOLOGY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Adamson, S. A.	On the Discovery of a Stone Implement in Alluvial Gravels at Barnsley	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	281	1887
Barnes, Rev. W.	Pilsdon	Dorset N. H. A. F. C.	"	VII.	102	1886
Bird, C.	Rochester Dene Holes	Rochester N. C.	*Roch. Naturalist*	16	265	1887
Carmichael, A.	The Place-names of Iona	R. Scot. Geog. Soc.	*Magazine*	{ II. III.	461 80, 242	1886 1887
Carpenter, Dr. A.	Recent Observations made in the New Road at Purley: Archæological and Ethnological	Croydon M. N. H. Club	*Proc. and Trans.*	3	24	1886
Carter, Dr. W.	Modern Scientific Theories of Man: Facts in Individual and Social Human Life—a Contrast	Liverpool Lit. Phil. Soc.	*Proc.*	XL.	1	"
Christy, R. W.	Notes on Boulders and Pits with Roman (?) Deposits near Roxwell, Essex	Essex F. C.	*Essex Naturalist*	I.	82	1887
Davis, J. W.	On the Relative Age of the Remains of Man in Yorkshire	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	201	"
Ellacombe, Rev. Canon	Place-names derived from Plants (in the Neighbourhood of Bath)	Bath N. H. A. F. C.	"	VI.	130	"

Fryer, W. H.	Notes on the Ancient Iron Workings at the Scowles	Cardiff Nat. Soc.	*Report and Trans.*	XVIII.	50	„
Gilchrist, Dr.	Notes on the Druidical Circle at Holywood	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	44	„
Harrison, F.	Old Cumberland Customs	Cumb. West. Assoc.	*Trans.*	XI.	53	1886
Holmes, J.	A Sketch of the Prehistoric Remains on Rombald's Moor	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	283	1887
Holmes, T. V.	Notes on the Evidence bearing upon British Ethnology	Essex F. C.	*Trans.*	IV.	189	1886
„ „	The Past and Future of the Essex Field Club. (Contains many references to the prehistoric remains in Essex)	„ „	*Essex Naturalist*	I.	64	1887
Horne, W.	On Prehistoric Remains recently discovered in Wensleydale	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	175	„
Jardine, W.	Local Superstitions	Cumb. West. Assoc.	*Trans.*	XI.	41	1886
Laver, H.	Early British Urns at Nayland, Suffolk, and Wix, Essex	Essex F. C.	*Essex Naturalist*	I.	35	1887
Lovett, E.	The Evolution of the Fishing-hook from the Flint Hook of Prehistoric Man to the Salmon Hook of the present day	Croydon M. N. H. Club	*Proc. and Trans.*	3	28	1886
M'Kie, J.	Galloway Place-names	Dum. Gal. N. H. Soc.	*Trans. and Proc.*	4	135	1887
Maclean, H.	Notes on Place-names of Iona	R. Scot. Geog. Soc.	*Magazine*	III.	35	„
Meiklejohn, Prof.	History, Poetry, &c., in Geographical Names	„ „ „	„	„	513	„
Mortimer, J. R.	On the Habitation Terraces of the East Riding	Yorks. Geol. Poly. Soc.	*Proc.*	IX.	221	„
Naden, Constance C. W.	The Data of Ethics	Birm. N. H. M. Soc.	*Mid. Naturalist*	X.	59, 92	„
Ransom, W.	An Account of British and Roman Remains found in the Neighbourhood of Hitchin	Herts N. H. Soc.	*Trans.*	IV.	39	1886
Rundle, Rev. S.	Cornubiana	Penz. N. H. A. Soc.	„	II.	257	„
Smith, W. G.	Primæval Man in the Valley of the Lea. (Two papers)	Essex F. C.	*Essex Naturalist*	I.	36, 83	1887
Spurrell, F. C. J.	Withambury	„ „	„ „	„	19	„
Stanley, W. F.	Notes upon the Evolution of the Highest Types of Human Form, within historical times, in the most highly civilised Nations	Croydon M. N. H. Club	*Proc. and Trans.*	3	69	1886
Stopes, H.	The Salting Mounds of Essex	Essex F. C.	*Essex Naturalist*	I.	96	1887
Various	Weights and Measurements of Boys at Marlborough College	Marlb. Coll. N. H. Soc.	*Report*	35	131	„
Wake, C. S.	The Anthropology of Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1886.	225	1886
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On the Vortex Theory of the Luminiferous Æther. (On the Propagation of Laminar Motion through a turbulently moving Inviscid Liquid.) *By* Sir WILLIAM THOMSON, *LL.D., F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

1. IN endeavouring to investigate turbulent motion of water between two fixed planes, for a promised communication to Section A of the British Association at its Meeting in Manchester, I have found something seemingly towards a solution (many times tried for within the last twenty years) of the problem to construct, by giving vortex motion to an incompressible inviscid fluid, a medium which shall transmit waves of laminar motion as the luminiferous æther transmits waves of light.

2. Let the fluid be unbounded on all sides, and let u, v, w be the velocity-components, and p the pressure at (x, y, z, t). We have

$$\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}=0 \quad . \quad . \quad . \quad . \quad (1),$$

$$\frac{du}{dt}=-\left(u\frac{du}{dx}+v\frac{du}{dy}+w\frac{du}{dz}+\frac{dp}{dx}\right) \quad . \quad . \quad . \quad (2),$$

$$\frac{dv}{dt}=-\left(u\frac{dv}{dx}+v\frac{dv}{dy}+w\frac{dv}{dz}+\frac{dp}{dy}\right) \quad . \quad . \quad . \quad (3),$$

$$\frac{dw}{dt}=-\left(u\frac{dw}{dx}+v\frac{dw}{dy}+w\frac{dw}{dz}+\frac{dp}{dz}\right) \quad . \quad . \quad . \quad (4),$$

From (2), (3), (4) we find, taking (1) into account,

$$-\nabla^2 p=\frac{du^2}{dx^2}+\frac{dv^2}{dy^2}+\frac{dw^2}{dz^2}+2\left(\frac{dv}{dz}\frac{dw}{dy}+\frac{dw}{dx}\frac{du}{dz}+\frac{du}{dy}\frac{dv}{dz}\right) \quad . \quad . \quad (5).$$

3. The velocity-components u, v, w may have any values whatever through all space, subject only to (1). Hence, on Fourier's principles, we have, as a perfectly comprehensive expression for the motion at any instant,

$$u=\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\, \alpha^{(e,\,f,\,g)}_{(m,\,n,\,q)} \sin(mx+e)\cos(ny+f)\cos(qz+g) \quad . \quad (6),$$

$$v=\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\, \beta^{(e,\,f,\,g)}_{(m,\,n,\,q)} \cos(mx+e)\sin(ny+f)\cos(qz+g) \quad . \quad (7),$$

$$w=\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\, \gamma^{(e,\,f,\,g)}_{(m,\,n,\,q)} \cos(mx+e)\cos(ny+f)\sin(qz+g) \quad . \quad (8);$$

where $\alpha^{(e,\,f,\,g)}_{(m,\,n,\,q)}$, $\beta^{(e,\,f,\,g)}_{(m,\,n,\,q)}$, $\gamma^{(e,\,f,\,g)}_{(m,\,n,\,q)}$ are any three velocities satisfying the equation

$$0=m\alpha^{(e,\,f,\,g)}_{(m,\,n,\,q)}+n\beta^{(e,\,f,\,g)}_{(m,\,n,\,q)}+q\gamma^{(e,\,f,\,g)}_{(m,\,n,\,q)} \quad . \quad . \quad . \quad (9);$$

and $\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma$ summation (or integration) for different values of m, n, q, e, f, g. The summations for e, f, g may, without loss of generality, be each confined to two values: $e=0$, and $e=\frac{1}{2}\pi$; $f=0$, and $f=\frac{1}{2}\pi$; $g=0$, and $g=\frac{1}{2}\pi$. We shall admit large values, and infinite values of m^{-1}, n^{-1}, q^{-1}, under certain conditions [§ 4 (10), (11), (12), and § 15 below], but otherwise we shall suppose the greatest value of each of them to be of some moderate, or exceedingly small, linear magnitude. This is an essential of the averagings to which we now proceed.

4. Let xav, xzav, xyzav denote space-averages, linear, surface, and solid, through infinitely great spaces, defined and illustrated by examples, each worked out from (6), (7), (8), as follows, L denoting an infinitely great length, or a very great multiple of whichever of m^{-1}, n^{-1}, q^{-1} may be concerned:—

$$\text{xav}\, u = \frac{1}{2\mathrm{L}}\int_{-\mathrm{L}}^{\mathrm{L}} dx\, u = \Sigma\Sigma\Sigma\Sigma a^{(\frac{1}{2}\pi, f, g)}_{(0,\, n,\, q)} \cos(ny+f)\cos(qz+g) \quad . \quad (10),$$

$$\text{xzav}\, u = \left(\frac{1}{2\mathrm{L}}\right)^2\int_{-\mathrm{L}}^{\mathrm{L}}\int_{-\mathrm{L}}^{\mathrm{L}} dz\, dx\, u = \sum_n^f\Sigma a^{(\frac{1}{2}\pi, f, 0)}_{(0,\, n,\, 0)} \cos(ny+f) \quad . \quad . \quad (11),$$

$$\text{xyzav}\, u = \left(\frac{1}{2\mathrm{L}}\right)^3\int_{-\mathrm{L}}^{\mathrm{L}}\int_{-\mathrm{L}}^{\mathrm{L}}\int_{-\mathrm{L}}^{\mathrm{L}} dz\, dy\, dx\, u = a^{(\frac{1}{2}\pi, 0, 0)}_{(0,\, 0,\, 0)} \quad . \quad . \quad . \quad (12),$$

$$\text{xav}\, u^2 = \tfrac{1}{2}\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\left[a^{(e,\, f,\, g)}_{(m,\, n,\, q)}\right] \cos^2(ny+f)\cos^2(qz+g) \quad . \quad . \quad (13);$$

this with the exceptions that

in the case of $m=0$, $e=0$, we take 0 in place of $\frac{1}{2}$,
and in the case of $m=0$, $e=\frac{1}{2}\pi$,, 1 ,, ,, .

$$\text{xzav}\, u^2 = \tfrac{1}{4}\sum_{m\, n\, q}^{e\, f\, g}\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma \left[a^{(e,\, f,\, g)}_{(m,\, n,\, q)}\right]^2 \cos^2(ny+f) \quad . \quad . \quad . \quad (14),$$

$$\text{xzav}\, uv = \tfrac{1}{4}\sum_{m\, n\, q}^{f\, g}\Sigma\Sigma\Sigma\Sigma \left[a^{(\frac{1}{2}\pi, f, g)}_{(m,\, n,\, q)}\beta^{(0,\, f,\, g)}_{(m,\, n,\, q)}\right.$$
$$\left. - a^{(0,\, f,\, g)}_{(m,\, n,\, q)}\beta^{(\frac{1}{2}\pi, f, g)}_{(m,\, n,\, q)}\right]\cos(ny+f)\sin(ny+f) \quad . \quad (15);$$

with the exceptions for (14) that

in the case of $m=0$ and $e=0$ }
and in the case of $q=0$ and $g=\frac{1}{2}\pi$ } we take 0 instead of $\frac{1}{4}$;
in the case of $m=0$ and $e=\frac{1}{2}\pi$ }
and in the case of $q=0$ and $g=0$ } ,, $\frac{1}{2}$,, ,, $\frac{1}{4}$;
in the case of $m=0$, $e=\frac{1}{2}\pi$, $n=0$, $f=\frac{1}{2}\pi$,, 1 ,, ,, $\frac{1}{4}$;
and analogous exceptions for (15).

$$\text{xyzav}\, u^2 = \tfrac{1}{8}\sum_{m\, n\, q}^{e\, f\, g}\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\left[a^{(e,\, f,\, g)}_{(m,\, n,\, q)}\right]^2 \quad . \quad . \quad . \quad (16),$$

with exceptions for zeros of m and q, analogous to those of (14).

5. As a last example of averagings for the present, take xyzav of (5). Thus we find

$$\left.\begin{aligned} -\text{xyzav}\,\nabla^2 p &= \tfrac{1}{8}\sum_{m\, n\, q}^{e\, f\, g}\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\left\{m a^{(e,\, f,\, g)}_{(m,\, n,\, q)} + n\beta^{(e,\, f,\, g)}_{(m,\, n,\, q)} + q\gamma^{(e,\, f,\, g)}_{(m,\, n,\, q)}\right\}^2 \\ &= 0 \text{ by } (9). \end{aligned}\right\} \quad . \quad (17).$$

The interpretation is obvious.

6. Remark, as a general property of this kind of averaging,

$$\text{xav}\frac{dQ}{dx} = 0 \quad . \quad . \quad . \quad . \quad . \quad (18),$$

Q be any quantity which is finite for infinitely great values of x.

7. Suppose now the motion to be homogeneously distributed through all space. This implies that the centres of inertia of all great volumes of the fluid have equal parallel motions, if any motions at all. Conveniently, therefore, we take our reference lines OX, OY, OZ, as fixed relatively to the centres of inertia of three (and therefore of all) centres of inertia of large volumes; in other words, we assume no translatory motion of the fluid as a whole. This makes zero of every large average of u and of v and of w; and, in passing, we may remark, with reference to our notation of § 3, that it makes, as we see by (10), (11), (12),

$$0=\alpha_{(0,n,q)}=\alpha_{(m,0,q)}=\alpha_{(m,n,0)}=\beta_{(0,n,q)}=\&c., \&c.=\gamma_{(m,n,0)} \quad . \quad (19).$$

Without for the present, however, encumbering ourselves with the Fourier-expression and notation of § 3, we may write, as the general expression for nullity of translational movement in large volumes,

$$0=\text{ave } u=\text{ave } v=\text{ave } w \quad . \quad . \quad . \quad (20);$$

where ave denotes the average through any great length of straight or curved line, or area of plane or curved surface, or through any great volume of space.

8. In terms of this generalised notation of averages, homogeneousness implies

$$\text{ave } u^2=\mathrm{U}^2, \quad \text{ave } v^2=\mathrm{V}^2, \quad \text{ave } w^2=\mathrm{W}^2 \quad . \quad . \quad (21),$$
$$\text{ave } vw=\mathrm{A}^2, \quad \text{ave } wu=\mathrm{B}^2, \quad \text{ave } uv=\mathrm{C}^2 \quad . \quad . \quad (22);$$

where U, V, W, A, B, C are six velocities independent of the positions of the spaces in which the averages are taken. These equations are, however, infinitely short of implying, though implied by, homogeneousness.

9. Suppose now the distribution of motion to be isotropic. This implies, but is infinitely more than is implied by, the following equations in terms of the notation of § 8, with further notation, R, to denote what we shall call THE AVERAGE VELOCITY of the turbulent motion:—

$$\mathrm{U}^2=\mathrm{V}^2=\mathrm{W}^2=\tfrac{1}{3}\mathrm{R}^2 \quad . \quad . \quad . \quad . \quad (23),$$
$$0=\mathrm{A}=\mathrm{B}=\mathrm{C} \quad . \quad . \quad . \quad . \quad . \quad (24).$$

10. Large questions now present themselves as to transformations which the distribution of turbulent motion will experience in an infinite liquid left to itself with any distribution given to it initially. If the initial distribution be homogeneous through all large volumes of space, except a certain large finite space, S, through which there is initially either no motion, or turbulent motion homogeneous or not, but not homogenous with the motion through the surrounding space, will the fluid which at any time is within S acquire more and more nearly as time advances the same homogeneous distribution of motion as that of the surrounding space, till ultimately the motion is homogeneous throughout?

11. If the answer were yes, could it be that this equalisation would come to pass through smaller and smaller spaces as time advances? In other words, would any given distribution, homogeneous on a large enough scale, become more and more *fine-grained* as time advances? Probably *yes* for some initial distributions; probably *no* for others. Probably *yes* for vortex motion given continuously through all of one large portion of the fluid, while all the rest is irrotational.

12. Probably *no* for the initial motion given in the shape of equal and similar Helmholtz rings, of proportions suitable for individual stability, and each of overall diameter considerably smaller than the average distance from nearest neighbours. Probably also *no*, though the rings be of very different volumes and vorticities. But probably *yes* if the diameters of the rings, or of many of them, be not small in comparison with distances from neighbours, or if the individual rings, each an endless slender filament, be entangled or nearly entangled among one another.

13. Again a question : If the initial distribution be *homogeneous and æolotropic*, will it become more and more isotropic as time advances, and *ultimately quite isotropic*? Probably *yes*, for any random initial distribution, whether of continuous rotationally-moving fluid or of separate finite vortex rings. Possibly *no* for some symmetrical initial distribution of vortex rings, conceivably stable.

14. If the initial distribution be homogeneous and isotropic (and therefore utterly *random* in respect to direction), will it remain so? Certainly *yes*. I proceed to investigate a mathematical formula, deducible from the answer, which will be of use to us later (§ 18). By (22) and (24) we have

$$\text{xzav } uv = 0, \text{ for all values of } t \quad . \quad . \quad . \quad (25).$$

But by (2) and (3) we find

$$\frac{d}{dt}(\text{xzav } uv) = -\text{xza}\left\{u\frac{d(uv)}{dx} + v\frac{d(uv)}{dy} + w\frac{d(uv)}{dz} + v\frac{dp}{dx} + u\frac{dp}{dy}\right\} \quad (26).$$

Hence

$$0 = \text{xzav}\left\{u\frac{d(uv)}{dx} + v\frac{d(uv)}{dy} + w\frac{d(uv)}{dz} + v\frac{dp}{dx} + u\frac{dp}{dy}\right\} \quad . \quad . \quad (27).$$

This equation in fact holds for every random case of motion satisfying (30) below, because positive and negative values of u, v, w are all equally probable, and therefore the value of the second member of (27) is doubled by adding to itself what it becomes when for u, v, w we substitute $-u$, $-v$, $-w$, which, it may be remarked, and verified by looking at (5), does not change the value of p.

15. We shall now suppose the initial motion to consist of a laminar motion $[f(y), 0, 0]$ superimposed on a homogeneous and isotropic distribution (u_0, v_0, w_0); so that we have

$$\text{when } t=0, \quad \mathrm{u}=f(y)+\mathrm{u}_0, \quad v=v_0, \quad w=w_0 \quad . \quad . \quad (28);$$

and we shall endeavour to find such a function, $f(y,t)$, that at any time t the velocity-components shall be

$$f(y,t)+\mathrm{u}, \; v, \; w \quad . \quad . \quad . \quad . \quad . \quad (29),$$

where u, v, w are quantities of each of which every large enough average is zero, so that particularly, for example,

$$0 = \text{xzav } \mathrm{u} = \text{xzav } v = \text{xzav } w \quad . \quad . \quad . \quad (30)$$

16. Substituting (29) for u, v, w in (2) we find

$$\frac{df(y,t)}{dt} + \frac{d\mathrm{u}}{dt} = -\left\{f(y,t)\frac{d\mathrm{u}}{dx} + v\frac{df(y,t)}{dy}\right\} - \left(\mathrm{u}\frac{d\mathrm{u}}{dx} + v\frac{d\mathrm{u}}{dy} + w\frac{d\mathrm{u}}{dz} + \frac{dp}{dx}\right) \quad (31)$$

Take now xzav of both members. The second term of the first member and the second term of the second member disappear, each in virtue of (30). The first and last terms of the second member disappear, each in virtue of (18) alone, and also each in virtue of (30). There remains

$$\frac{df(y,t)}{dt} = -\text{xzav}\left(\mathrm{u}\frac{d\mathrm{u}}{dx} + v\frac{d\mathrm{u}}{dy} + w\frac{d\mathrm{u}}{dz}\right) \quad . \quad . \quad (32).$$

To simplify, add to the second member [by (1)]

$$0 = -\text{xzav}\left(\mathrm{u}\frac{d\mathrm{u}}{dx} + \mathrm{u}\frac{dv}{dy} + \mathrm{u}\frac{dw}{dz}\right) \quad . \quad . \quad . \quad (33);$$

and, the first and third pair of terms of the thus-modified second member vanishing by (18), find

$$\frac{df(y,t)}{dt} = -\text{xzav}\frac{d(\mathrm{u}v)}{dy} \quad . \quad . \quad . \quad . \quad (34).$$

It is to be remarked that this result involves, besides (1), no other condition respecting (u, v, w) than (30); no isotropy, no homogeneousness in respect to y; and only homogeneousness of *régime* with respect to y and z, with no mean translational motion.

The x-translational mean component of the motion is wholly represented by $f(y,t)$, and, so far as our establishment of (34) is concerned, may be of any magnitude, great or small relatively to velocity-components of the turbulent motion. It is a fundamental formula in the theory of the turbulent motion of water between two planes; and I had found it in endeavouring to treat mathematically my brother Professor James Thomson's theory of the 'Flow of Water in Uniform *Régime* in Rivers and other Open Channels.'[1] In endeavouring to advance a step towards the law of distribution of the laminar motion at different depths, I was surprised to discover the seeming possibility of a law of propagation as of distortional waves in an elastic solid, which constitutes the conclusion of my present communication, on the supposition of § 15 that the distribution u_0, v_0, w_0 is isotropic, and that $df(y,t)/dy$, divided by the greatest value of $f(y,t)$, is infinitely small in comparison with the smallest values of m, n, q, in the Fourier-formulæ (6), (7), (8) for the turbulent motion.

17. By (34) we see that, if the turbulent motion remained, through time, isotropic as at the beginning, $f(y,t)$ would remain constantly at its initial value $f(y)$. To find whether the turbulent motion does remain isotropic, and, if it does not, to find what we want to know of its deviation from isotropy, let us find $\text{xzav}\frac{d(\mathrm{u}v)}{dt}$, by (2) and (3), as follows:—First, by multiplying (31) by v, and (3) by u, and adding, we find

$$v\frac{df(y,t)}{dt} + \frac{d(\mathrm{u}v)}{dt} = -\left\{f(y,t)\frac{d(\mathrm{u}v)}{dx} + v^2\frac{df(y,t)}{dy}\right\}$$
$$-\left\{\mathrm{u}\frac{d(\mathrm{u}v)}{dx} + v\frac{d(\mathrm{u}v)}{dy} + w\frac{d(\mathrm{u}v)}{dz} + v\frac{dp}{dx} + \mathrm{u}\frac{dp}{dy}\right\} \quad . \quad (35).$$

Taking xzav of this, and remarking that the first term of the first member disappears by (30), and the first term of the second member by (18), we

[1] *Proceedings of the Royal Society*, Aug. 15, 1878.

find, with V^2, as in §§ 8, 9, to denote the average y-component-velocity of the turbulent motion,

$$\frac{d}{dt}\{\text{xzav}(\mathfrak{u}v)\} = -V^2\frac{df(y,t)}{dy} - Q \quad . \quad . \quad . \quad (36),$$

where

$$Q = \text{xzav}\left\{\mathfrak{u}\frac{d(\mathfrak{u}v)}{dx} + v\frac{d(\mathfrak{u}v)}{dy} + w\frac{d(\mathfrak{u}v)}{dz} + v\frac{dp}{dx} + \mathfrak{u}\frac{dp}{dy}\right\} \quad . \quad (37).$$

18. Let

$$p = \mathfrak{p} + \varpi \quad . \quad . \quad . \quad . \quad (38),$$

where $\mathfrak{p}$ denotes what p would be if f were zero. We find, by (5),

$$-\nabla^2\varpi = 2\frac{df(y,t)}{dy}\frac{dv}{dx} \quad . \quad . \quad . \quad . \quad . \quad (39),$$

and, by (27) and (37),

$$Q = \text{xzav}\left(v\frac{d\varpi}{dx} + \mathfrak{u}\frac{d\varpi}{dy}\right) \quad . \quad . \quad . \quad . \quad . \quad (40),$$

So far we have not used either the supposition of initial isotropy for the turbulent motion, or of the infinitesimalness of df/dy. We now must introduce and use both suppositions.

19. To facilitate the integration of (39), we now use our supposition that $\frac{d}{dt}f(y,t)$, divided by the greatest value of $f(y,t)$, is infinitely small in comparison with m, n, q, which, as is easily proved, gives

$$\varpi = 2\frac{df(y,t)}{dy}\,\frac{1}{-\nabla^2}\frac{dv}{dx} \quad . \quad . \quad . \quad . \quad (41),$$

by which (40) becomes

$$Q = -2\frac{df(y,t)}{dy}\text{xzav}\left(v\frac{d}{dx} + \mathfrak{u}\frac{d}{dy}\right)\nabla^{-2}\frac{dv}{dx} \quad . \quad . \quad (42).$$

Now, by (x, z) isotropy, we have

$$2\text{xzav}\left(v_0\frac{d}{dx} + \mathfrak{u}_0\frac{d}{dy}\right)\nabla^{-2}\frac{dv_0}{dx}$$

$$= \text{xzav}\left\{v_0\left(\frac{d^2}{dx^2} + \frac{d^2}{dz^2}\right) + \left(\mathfrak{u}_0\frac{d}{dx} + w_0\frac{d}{dz}\right)\frac{d}{dy}\right\}\nabla^{-2}v_0 \quad . \quad . \quad (43).$$

Performing integrations by parts for the last two terms of the second member, and using (1), we find

$$\text{xzav}\left(\mathfrak{u}_0\frac{d}{dx} + w_0\frac{d}{dz}\right)\frac{d}{dy}\nabla^{-2}v_0 = -\text{xzav}\left(\frac{d\mathfrak{u}_0}{dx} + \frac{dw_0}{dz}\right)\frac{d}{dy}\nabla^{-2}v_0$$

$$= \text{xzav}\,\frac{dv_0}{dy}\,\frac{d}{dy}\nabla^{-2}v_0\,;$$

and so we find, by (43) and (42),

$$Q_0 = -\frac{df(y,t)}{dy}\text{xzav}\left\{v_0\left(\frac{d^2}{dx^2} + \frac{d^2}{dz^2}\right) + \frac{dv_0}{dy}\frac{d}{dy}\right\}\nabla^{-2}v_0 \quad . \quad (44)$$

20. Using now the Fourier expansion (7) for v_0, we find

$$-\Delta^{-2}v_0 = \sum_q \overset{e}{\Sigma}\overset{f}{\Sigma}\overset{g}{\Sigma}\Sigma\Sigma\Sigma\,\beta^{(e,f,g)}_{(m,n,q)}\frac{\cos(mx+e)\sin(ny+f)\cos(qz+g)}{m^2+n^2+q^2} \quad (45).$$

Hence we find (with suffixes &c. dropped),

$$\text{xzav}\frac{dv_0}{dy}\frac{d}{dy}\Delta^{-2}v_0=-\tfrac{1}{8}\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\frac{n^2\beta^2}{m^2+n^2+q^2} \quad . \quad . \quad (46)^1,$$

and

$$\text{xzav}\ v_0\left(\frac{d^2}{dx^2}+\frac{d^2}{dz^2}\right)\Delta^{-2}v_0=\tfrac{1}{8}\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\frac{(m^2+q^2)\beta^2}{m^2+n^2+q^2} \quad . \quad . \quad (47).$$

Now, in virtue of the average uniformity of the constituent terms implied in isotropy and homogeneousness (§§ 7, 8, 9), the second member of (46) is equal to $-\frac{1}{8}\Sigma\Sigma\Sigma\Sigma\Sigma\Sigma\ \frac{\beta^2}{3}$, and therefore (§ 9) equal to $-\frac{1}{9}R^2$; and similarly we see that the second member of (47) is equal to $+\frac{2}{9}R^2$. Hence, finally, by (44),

$$Q_0=-\tfrac{1}{9}R^2\frac{df(y,t)}{dy} \quad . \quad . \quad . \quad . \quad (48);$$

and (36) for $t=0$, with $\frac{1}{3}R^2$ for V^2 on account of isotropy, becomes

$$\left\{\frac{d}{dt}\text{xzav}\ (uv)\right\}_{t=0}=-\tfrac{2}{9}R^2\left\{\frac{df(y,t)}{dy}\right\}_{t=0} \quad . \quad . \quad (49).$$

The deviation from isotropy, which this equation shows, is very small, because of the smallness of df/dy; and (27) does not need isotropy, but holds in virtue of (30). Hence (49) is not confined to the initial values (values for $t=0$) of the two members, because we neglect an infinitesimal deviation from $\frac{2}{9}R^2$ in the first factor of the second member, considering the smallness of the second factor. Hence, for all values of t, unless so far as the 'random' character referred to at the end of §13 may be lost by a rearrangement of vortices vitiating (27),

$$\frac{d}{dt}\text{xzav}\ (uv)=-\tfrac{2}{9}R^2\frac{df(y,t)}{dy} \quad . \quad . \quad . \quad (50).$$

21. Eliminating the first member from this equation, by (34), we find

$$\frac{d^2f}{dt^2}=\tfrac{2}{9}R^2\ \frac{d^2f}{dy^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (51).$$

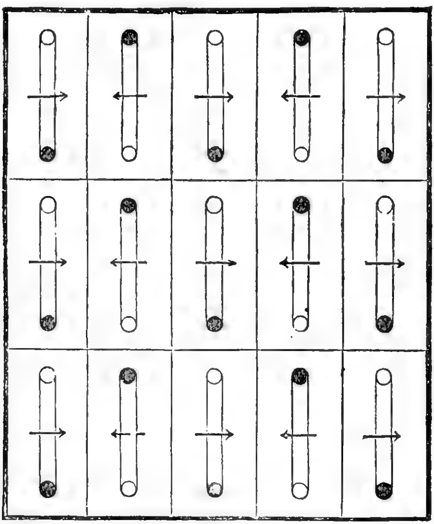
Thus we have the very remarkable result that laminar disturbance is propagated according to the well-known mode of waves of distortion in a homogeneous elastic solid; and that the velocity of propagation is $\frac{\sqrt{2}}{3}R$, or about ·47 of the average velocity of the turbulent motion of the fluid. This might seem to go far towards giving probability to the vortex theory of the luminiferous æther, were it not for the doubtful proviso at the end of § 20.

22. If the undisturbed condition of the medium be a stable symmetrical distribution of vortex-rings the suggested vitiation by 'rearrangement' cannot occur. For example, let it be such as is represented in

[1] Here and henceforth an averaging through y-spaces so small as to cover no sensible differences of $f(y,t)$, but infinitely large in proportion to n^{-1}, is implied.

fig. 1, where the small white and black circles represent cross sections of the rings: the white where the rotation is opposite to, and the black where it is in the same direction as, the rotation of the hands of a watch placed on the diagram facing towards the spectator. Imagine first each vortex-ring to be in a portion of the fluid contained within a rigid rectangular box, of which four sides are indicated by the fine lines crossing one another at right angles throughout the diagram; and the other pair are parallel to the paper, at any distance asunder we like to imagine. Supposing the volume of rotationally moving portion of the fluid constituting the ring to be given, there is clearly one determinate shape, and diametral magnitude, in which it must be given in order that the motion may be steady. Let it be so given, and fill space with such rectangular boxes of vortices arranged facing one another oppositely in the manner shown in the diagram. Annul now the rigidity of the sides of the boxes. The motion continues unchangedly steady. But is it stable, now that the rigid partitions are done away with? No proof has yet been given that

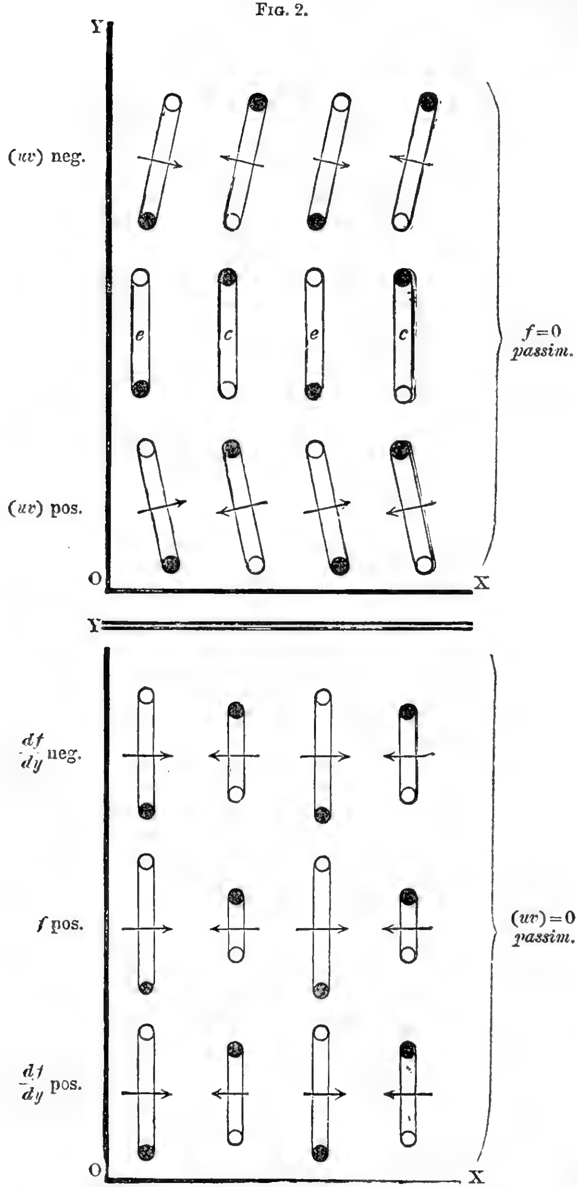
Fig. 1.



it is. If it is, laminar waves, such as waves of light, could be propagated through it; and the velocity of propagation would be $R\sqrt{2/3}$ if the sides of the ideal boxes parallel to the undisturbed planes of the rings are square (which makes ave $u^2 =$ ave w^2), and if the distance between the square sides of each box bears the proper ratio to the side of the square to make ave $v^2 =$ ave $u^2 =$ ave w^2.

23. Consider now, for example, plane waves, or laminar vibrations, in planes perpendicular to the undisturbed planes of the rings. The change of configuration of the vortices in the course of a quarter period of a harmonic standing vibration, $f(y,t) = \sin \omega t \cos \kappa g$ (which is more easily illustrated diagrammatically than a wave or succession of waves), is illustrated in fig. 2, for a portion of the fluid on each side of $y=0$. The

Fig. 2.



Here (uv) means an average of the kind described in the footnote on (46); e, e are rings which are being expanded; and c, c are rings which are being contracted.

upper part of the diagram represents the state of affairs when $t=0$; the lower when $t=\pi/(2\omega)$. But it must not be overlooked, that all this (§§ 22, 23) depends on the unproved assumption that the symmetrical arrangement is *stable.*

24. It is exceedingly doubtful, so far as I can judge after much anxious consideration from time to time during these last twenty years, whether the configuration represented in fig. 1, or any other symmetrical arrangement, is stable when the rigidity of the ideal partitions enclosing each ring separately is annulled throughout space. It is possible that the rigidity of two, three, or more of the partitions may be annulled without vitiating the stability of the steady symmetric motion; but that if it be annulled through the whole of space, for all the partitions, the symmetric motion is unstable, and the rings shuffle themselves into perpetually varying relative positions, with *average homogeneousness,* like the ultimate molecules of a homogeneous liquid. I cannot see how, under these conditions, the 'vitiating rearrangement' referred to at the end of § 20 can be expected not to take place within the period of a wave or vibration. To suppose the overall diameter of each ring to be very small in proportion to its average distances from neighbours, so that the crowd would be analogous rather to the molecules of a gas than to those of a liquid, would not help us to escape the vitiating rearrangement which would be analogous to that investigated by Maxwell in his admirable kinetic theory of the viscosity of gases. I am thus driven to admit, in conclusion, that the most favourable verdict I can ask for the propagation of laminar waves through a turbulently moving inviscid liquid is the Scottish verdict of *not proven.*

On the Theory of Electric Endosmose and other Allied Phenomena, and on the Existence of a Sliding Coefficient for a Fluid in contact with a Solid. By Professor HORACE LAMB, *M.A., F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

THE laws governing the electric transport of conducting liquids through the walls of porous vessels or along capillary tubes, and other related phenomena, have been investigated experimentally by Wiedemann [1] and Quincke,[2] and explained by the latter writer on the assumption of a contact difference of potential between the fluid and its solid boundaries. This explanation has been developed mathematically by von Helmholtz in his well-known paper on electric double layers.[3] Applying the known laws of motion of viscous fluids, he finds that the calculated results, so far as they depend on quantities which admit of measurement, are in satisfactory agreement with the experiments, and that the values which it is necessary to assign to the contact difference above spoken of are in all cases comparable with the electromotive force of a Daniell's cell. Incidentally he arrives also at the conclusion that in the cases considered there is no slipping of the fluid over the surface of the solids with which it is in contact.

[1] *Pogg. Ann.* lxxxvii. 1852, and xcix. 1856.

[2] *Ibid.* cxiii. 1861. An excellent summary is given in Wiedemann's *Elektricität* ii. pp. 166 *et seq.*

[3] *Wied. Ann.* vii. 1879; or *Collected Papers,* i. p. 855.

In the present paper a slightly different view is adopted on this latter point. It is assumed that a solid offers a very great, but not an infinite, resistance to the sliding of a fluid over it, and that this sliding is an essential factor in the phenomena referred to. On this modified hypothesis the various cases treated by von Helmholtz are discussed, and in some respects extended. In all cases the results differ from those obtained by von Helmholtz by a factor l/d, where l is a linear magnitude measuring the 'slip,' and d is the distance between the plates of an air condenser equivalent to that virtually formed by the opposed surfaces of solid and fluid. For instance, comparing with the experimental results of Wiedemann, von Helmholtz infers that for a certain solution of $CuSO_4$ in contact with the material of a porous clay vessel,

$$E/D=1{\cdot}77,$$

where E is the contact difference of potential, and D the E.M.F. of a Daniell's cell. On the views adopted in this paper, the inference would be—

$$\frac{E}{D}\cdot\frac{l}{d}=1{\cdot}77.$$

Since this involves *two* unknown ratios, no such definite conclusion as to the value of E can be drawn; but it is evident that the phenomena are consistent even with very small values of E/D, provided l be a sufficient multiple of d. Since this quantity d is of molecular order of magnitude (comparable probably with 10^{-8}cm.), l may still be so small that the effects of slipping would be entirely insensible in such experiments as those of Poiseuille.

1. In Wiedemann's experiments the poles of a galvanic battery were connected with two metal plates immersed in a conducting liquid (for instance, copper plates in a solution of $CuSO_4$) and separated by a porous partition. In one set of experiments the liquid was maintained at the same level on the two sides, and the amount carried by 'electric endosmose' through the pores was measured by the overflow on the further side. This amount was found to be proportional to the total amount of electricity conveyed by the current, and independent of the area or of the thickness of the porous partition. For solutions of the same salt, but of different degrees of concentration, the amount of fluid carried across was roughly proportional to the specific electric resistance.

As typical of this class of experiment, von Helmholtz considers the case of a straight tube of uniform section, made of insulating material, and containing a liquid through which an electric current is made to flow. Taking the axis of x parallel to the length of the tube, let u be the velocity of the fluid at any point, μ the coefficient of viscosity, β the coefficient of sliding friction of the fluid in contact with the wall of the tube. Considering the forces acting on a thin surface film, and denoting by dn an element of the inwardly directed normal, we find—

$$\mu\frac{du}{dn}-\beta u+X=0 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where the first term is due to the fluid friction on the inner surface of the film, the second to the friction between the outer surface and the tube, while the third term represents the external forces reckoned per unit area. In all ordinary hydrodynamical questions the latter term is

absent, but in the present case we have forces due to the fall of potential along the tube, acting on the superficial layer. Let E be the excess of potential of the liquid in contact with the wall of the tube over that of the wall itself. It has been pointed out by von Helmholtz that a discontinuity of potential implies the existence, over the surface of discontinuity, of a 'double layer' of positive and negative electricity (analogous to the magnetic shells of Ampère), the difference of potential on the two sides being equal to 4π times the *electrical moment* of the layer. We therefore suppose that in our present case there exists in a thin superficial stratum of the fluid a distribution of electricity whose amount per unit area is ρ, say, whilst in a thin superficial stratum of the solid there is a complementary distribution $-\rho$. If d denote (in an obvious sense) the mean distance between these distributions, we have

$$E = 4\pi\rho d,$$

or

$$\rho = c\mathrm{E} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

if

$$c = 1/4\pi d,$$

that is, c denotes the capacity per unit area of the quasi-condenser formed by the opposed surfaces of solid and fluid. For the case of metallic electrodes (platinum, mercury) in contact with acidulated water, von Helmholtz and Lippmann have independently found the value of d to be comparable with 10^{-8} cm., and we may reasonably suppose it to be of a similar order of magnitude in the cases at present under consideration.

If ϕ denote the electric potential at any point in the interior of the fluid, we have

$$X = -\rho\frac{d\phi}{dx} \quad . \quad . \quad . \quad . \quad (3)$$

If Q be the sectional area of the tube, J the electric current through it, σ the specific resistance of the liquid, we have, by Ohm's law—

$$-\frac{d\phi}{dx} = \frac{\sigma \mathrm{J}}{\mathrm{Q}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

When the motion has become steady, there being no difference of fluid pressure between the two ends of the tube, the velocity u will be uniform over the section, so that the equation (1) becomes

$$\beta u = \frac{\sigma \mathrm{J}}{\mathrm{Q}}\rho \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and therefore the total flux per second is

$$\mathrm{U} = u\mathrm{Q} = \frac{\sigma \mathrm{J}}{\beta}\,\mathrm{E} \quad . \quad . \quad . \quad . \quad (6)$$

Since in most cases the flux is in the positive direction of the electric current, we must assume that, as a rule, E is positive, *i.e.*, the fluid is positive relatively to the solid.[1]

To compare with von Helmholtz's result let us write

$$c = 1/4\pi d \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

[1] The most noteworthy exception appears to be oil of turpentine in contact with glass or clay. In contact with sulphur, on the other hand, it appears to be positive. (Quincke.)

as before, and

$$\mu/\beta = l \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The constant l, which is of the nature of a line, measures, as it were, the facility of slipping. In ordinary hydrodynamical problems, in which there is no question of external surface-forces, the surface condition (1) reduces to

$$u = l\frac{du}{dn} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The motion will then be sensibly the same as it would be on the hypothesis of no slipping, provided a layer of thickness l were removed from the surface of the solid and replaced by fluid, it being supposed that l is small compared with all the dimensions of the space occupied by fluid.

On making the substitutions (7) and (8), the formula (6) becomes

$$\mathrm{U} = \frac{\sigma \mathrm{J}}{4\pi\mu} \cdot \frac{l}{d} \cdot \mathrm{E} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

which differs from von Helmholtz's result only in containing the factor l/d.

In one respect the difference between the view here taken and that adopted by von Helmholtz is little more than verbal. Von Helmholtz considers that the velocity u is practically uniform over the section of the tube, except near the wall, where it falls rapidly to zero. The stratum within which this fall is supposed to take place is that occupied by the (probably) molecular charges of electricity, whose aggregate is represented by ρ. The two views might perhaps be reconciled by interpreting von Helmholtz's investigation as virtually a proof that $l = d$, if it were not for the assumption that the equations of motion of a viscous fluid, as well as the electrostatic equation

$$\nabla^2\phi + 4\mu\epsilon = 0$$

(where $\nabla^2 = d^2/dx^2 + d^2/dy^2 + d^2/dz^2$, and ϵ is the volume-density of free electricity), may be supposed to hold through the thickness of the stratum in question. Since these equations are only true in a statistical sense, when the linear elements dx, dy, dz are taken to be large in comparison with the average distance between neighbouring molecules, whereas the thickness of the stratum is almost certainly not more than a very moderate multiple of this distance, it seems doubtful whether they can fairly be pressed into service in the manner indicated.

Although we have only somewhat vague probabilities to guide us, it appears reasonable to suppose, from what we know of contact differences of potential in cases where they can be measured, that the ratio E/D will not very greatly exceed or fall below unity; that it will lie, say, between about ·1 and 10. If this be so, the comparison of our theory with the observations entitles us to say that the sliding coefficient l is at all events of the same order of magnitude as d. If for water in contact with glass l were equal to 10^{-8} cm., this would make

$$\beta = \mu/l = 1{\cdot}4 \times 10^6 \text{ C.G.S.};$$

in other words, the shearing stress necessary (in the absence of electrical surface forces) to produce a sliding of one centimètre per second would be 1·4 megadynes per square centimètre. It follows that the effects of slipping would be utterly insensible in ordinary hydrodynamical questions,

e.g., the experiments of Poiseuille. The slipping leads to appreciable results in the cases at present in view, only in consequence of the relatively enormous electrical forces acting on the superficial film, and dragging the fluid (as it were) by the skin, through the tube.

The formula (6) may be written—

$$\frac{\text{Flux of liquid}}{\text{Flux of electricity}} = \frac{\sigma c \mathrm{E}}{\beta} \quad . \quad . \quad . \quad . \quad (11)$$

In this form it can be shown to be true, under a certain restriction, for a tube of varying section, for a network of tubes, and even for the labyrinth of channels contained in the walls of a porous vessel, provided no difference of pressure be allowed to establish itself on the two sides.

Let ϕ denote as before the electric potential at any point of the fluid It will appear that all the conditions of our problem will be satisfied if we suppose the motion of the fluid to be irrotational, the velocity-potential χ being everywhere proportional to ϕ.

Since $\nabla^2\chi = 0$, the equations of steady small motion of a viscous liquid, viz.—

$$\left.\begin{aligned} -\frac{dp}{dx} + \mu\nabla^2 u = 0 \\ -\frac{dp}{dy} + \mu\nabla^2 v = 0 \\ -\frac{dp}{dz} + \mu\nabla^2 w = 0 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

are satisfied by $p =$ const. To form the boundary condition corresponding to (1), let ds be a linear element drawn on the surface in the direction of the flow of liquid, and therefore also of electricity. We obtain—

$$\mu f - \beta\frac{d\chi}{ds} - \rho\frac{d\phi}{ds} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

where f is the rate of shear in a plane through ds normal to the surface. If l be small in comparison with the linear dimensions of the channels the first term of this equation may, in the cases at present under consideration, be neglected in comparison with the rest,[1] so that (13) is satisfied provided—

$$\chi = -\frac{\rho}{\beta}\phi \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

everywhere. Hence the flow of liquid is everywhere in the same

[1] To see this, take the origin at any point of the boundary, and the axis of z along the normal, and let the equation to the boundary then be

$$z = \tfrac{1}{2}(\mathrm{A}x^2 + 2\mathrm{B}xy + \mathrm{C}y^2) + \&c.$$

If the axis of x be in the direction of the flow at O, we have to prove that $ld^2\chi/dxdz$ may be neglected in comparison with $d\chi/dx$. It is proved in the appendix to this paper that at O we must have

$$\frac{dw}{dx} = \mathrm{A}u + \mathrm{B}v,$$

and therefore

$$l\frac{d^2\chi}{dxdz} = l\mathrm{A}\,.\frac{d\chi}{dx},$$

which proves the statement made above, when l is small in comparison with the radii of curvature of the wall.

direction as that of electricity, and stands to it in the ratio of χ to $-\phi/\sigma$, that is, in the ratio $\sigma\rho/\beta$. The formula (11) embraces all the laws discovered experimentally by Wiedemann for the electric transport of liquids through porous vessels.

2. If a difference of pressure obtains between the two sides of a porous wall, or between the two ends of a capillary tube, the flux above calculated must be superposed on that which would be maintained (as in Poiseuille's experiments) by this difference of pressure in the absence of electrical forces. This follows at once from the linearity of the equations. Wiedemann and Quincke have made experiments in which the fluxes of liquid due to the two causes just balance one another, the subject of measurement being the difference of pressure which exists between the two sides when this equilibrium is established. In Wiedemann's experiments the difference of pressure maintained in this way between the two sides of a porous partition was found to vary directly as the strength of the electric current, inversely as the area of the porous wall, and directly as its thickness. For solutions of different degrees of concentration the pressure was proportional to the electric resistance.

In the case of a tube of uniform circular section, treated by von Helmholtz, taking the axis of x along the axis of the tube, and using cylindrical coordinates x, r, the first of the equations (12) becomes

$$\frac{dp}{dx}=\mu\left(\frac{d^2u}{dr^2}+\frac{1}{r}\frac{du}{dr}\right) \quad . \quad . \quad . \quad . \quad (15)$$

Here p is a function of x only, u one of r only. Hence each side of the equation must be constant and $=\mathrm{P}/\mathrm{L}$, where L is the length of the tube, and P the difference of pressure between its ends. Hence

$$u=\frac{\mathrm{P}}{4\mu\mathrm{L}}r^2+\mathrm{C}.$$

Determining C so that the integral flux across the section is zero, we find

$$u=\frac{\mathrm{P}}{4\mu\mathrm{L}}\left(r^2-\frac{\mathrm{R}^2}{2}\right) \quad . \quad . \quad . \quad . \quad (16)$$

The velocities close to the wall and in the axis of the tube are equal and opposite. The surface condition, viz.

$$-\mu\frac{du}{dr}-\beta u-\rho\frac{d\phi}{dx}=0 \quad . \quad . \quad . \quad (17)$$

leads, since

$$\frac{d\phi}{dx}=-\frac{\sigma\mathrm{J}}{\pi\mathrm{R}^2},$$

to

$$\mathrm{P}=\frac{8\mu\mathrm{L}}{\pi\mathrm{R}^4(1+4\mu/\beta\mathrm{R})}\cdot\frac{\sigma\mathrm{J}}{\beta}\cdot\rho$$

$$=\frac{2\sigma\mathrm{JL}}{\pi^2\mathrm{R}^4(1+4l/\mathrm{R})}\cdot\frac{l}{d}\cdot\mathrm{E}.$$

If A denote the total E.M.F. along the tube, and if we neglect the small term l/R in the denominator, we get

$$\mathrm{P}=\frac{2\mathrm{A}}{\pi\mathrm{R}^2}\cdot\frac{l}{d}\cdot\mathrm{E}\,. \quad . \quad . \quad . \quad . \quad (18)$$

which again differs from von Helmholtz's result only in containing the factor l/d. The comparison with Quincke's experiments on the discharge of Leyden jars, &c., through a column of liquid in a slightly inclined capillary tube can then be made exactly as in von Helmholtz's paper.

The result contained in (18) can be generalised. Taking, for example, the case of a porous vessel, it has been shown that the flux of liquid due to electrical causes is

$$\frac{\sigma c \mathrm{E}}{\beta} \times \text{flux of electricity.}$$

The flux due to the difference of pressure P on the two sides is

$$-\mathrm{P}/\mathrm{K},$$

where K is a constant depending on the form and arrangement of the channels and on the values of μ and β. This constant might be called the 'hydraulic resistance' of the system of channels. Equating the total flux of liquid to zero, we find

$$\mathrm{P}=\frac{\mathrm{K}\sigma c \mathrm{E}}{\beta} \times \text{flux of electricity} \quad . \quad . \quad . \quad . \quad (19)$$

For a tube of uniform circular section we have, neglecting l/R,

$$\mathrm{K}=8\mu\mathrm{L}/\pi\mathrm{R}^4,$$

leading to our previous result.

3. Quincke has also made observations on the motion of fine particles suspended in a liquid through which electric currents are flowing. For instance, in the case discussed in § 2, where, under the influence of an electric current, the fluid in a tube of circular section flows (as a rule) forwards along the walls and backwards along the axis, the integral flux across any section being zero, he found, using a glass tube ·4 mm. in diameter, that for a certain strength of current the particles near the axis move backwards, whilst those near the walls move forwards, though with less velocity. For stronger currents the motion of the suspended particles is everywhere backwards, but more rapid the nearer to the axis. In narrower tubes the motion was everywhere backwards, even with the feeblest currents which were sufficient to produce perceptible motion at all.

These phenomena have been explained in a general manner by Quincke and von Helmholtz. If E denote the contact-difference of potential between the solid particle and the fluid, we have electrifications $\mp c\mathrm{E}$ on the opposed surfaces, which are therefore urged in opposite directions by the electric forces whose components are $-d\phi/dx$, $-d\phi/dy$, $-d\phi/dz$.

The principles of this paper lead to a very simple expression for the velocity of an isolated particle when the motion has become steady, viz., the velocity relative to the fluid in this neighbourhood is in the direction of the electric current, and its amount is

$$\mathrm{V}=-\mathrm{C}\rho/\beta \quad . \quad . \quad . \quad . \quad . \quad (20)$$

where C denotes the gradient of electric potential, and ρ, β have the same meanings as before. To prove this take the axis of x parallel to the general direction of the electric current in the neighbourhood of the particle. The problem is virtually unaltered if we suppose the fluid to flow with the general velocity $-\mathrm{V}$ past the solid, which is at rest. The electric potential at a distance from the solid will be of the form

$$\phi = -Cx + S_0 + S_{-2} + S_{-3} + \quad . \quad . \quad . \quad . \quad (21)$$

where S_0, S_{-2}, S_{-3} . . . are solid harmonics of the degrees indicated. These latter terms represent the disturbance of the otherwise uniform flow of electricity by the presence of the insulating solid particles. It will be found that all the conditions of our problem are satisfied by supposing the fluid motion to be irrotational. We therefore write for the velocity potential at a distance

$$\chi = -Vx + T_0 + T_{-2} + T_{-3} + \quad . \quad . \quad . \quad (22)$$

where T_0, T_{-2}, T_{-3} . . . are solid harmonics. The surface condition will be of the form (13), in which we may neglect the first term if we suppose the quantity l defined by (8) to be small in comparison with the dimensions of the particle.[1] Hence the condition is satisfied provided

$$\chi = -\frac{\rho}{\beta}\phi \quad . \quad . \quad . \quad . \quad (23)$$

and therefore

$$V = -C\rho/\beta \quad . \quad . \quad . \quad . \quad (24)$$

In order to satisfy ourselves that the assumption (23) makes the resultant force and couple on the sphere equal to zero, it will be sufficient to show that the force and couple-resultants of the stress across a closed surface Σ_1 drawn in the fluid and just enclosing the solid are zero. Using a common notation for the components of stress at any point of the fluid we have

$$\left.\begin{aligned} p_{xx} &= -p + 2\mu\frac{d^2\chi}{dx^2}, \text{ \&c., \&c.} \\ p_{yz} &= 2\mu\,\frac{d^2\chi}{dydz}, \text{ \&c., \&c.} \end{aligned}\right\} \quad . \quad . \quad . \quad (25)$$

where p is constant, by (12). The resultant stress parallel to x across the complete boundary Σ of any space occupied by fluid is

$$\iint(lp_{xx} + mp_{xy} + np_{xz})d\Sigma,$$

where l, m, n are the direction-cosines of the normal to any element $d\Sigma$ of the boundary. This surface-integral is equal to the volume-integral

$$\iiint\left(\frac{dp_{xx}}{dx} + \frac{dp_{xy}}{dy} + \frac{dp_{xz}}{dz}\right)dxdydz$$

taken throughout the interior of Σ, which vanishes, by (25), since $\nabla^2\chi = 0$. In a similar manner it may be shown that the couple-resultant of the stress across Σ is zero. Now let Σ be made up of the surface Σ_1 above defined, and of a sphere Σ_2 of infinite radius having its centre at the origin. It follows that the stresses across Σ_1 are statically equivalent to those across Σ_2. And it easily follows from (22) that the latter stresses are in equilibrium.

It is remarkable that the velocity (24) is independent of the size or shape of the particle, so long as its dimensions are large in comparison with l. This velocity is, of course, to be superposed on that of the fluid

[1] For the case of a sphere of radius R, I find without making this approximation that

$$V = -\frac{C\rho}{\beta}(1 + 2l/R).$$

in the neighbourhood. For instance, in the circumstances of Quincke's experiments we have

$$C = \frac{\sigma J}{\pi R^2},$$

and, therefore, for a suspended particle of the same nature as the walls of the tube we should have for the absolute velocity the value

$$-\frac{3}{2}\frac{\sigma J}{\pi R^2} \cdot \frac{cE}{\beta}$$

when the particle is in the axis, and

$$-\frac{1}{2}\frac{\sigma J}{\pi R^2} \cdot \frac{cE}{\beta}$$

when it is near the walls.[1]

4. We may next consider the electromotive forces produced by the passage of a liquid through a capillary tube or a porous diaphragm. This subject has been studied experimentally by Quincke, Edlund, Haga, Clark, and more recently by Dorn,[2] the general result being that the potential is higher on the side where the pressure is least by an amount proportional to the difference of pressure. The phenomenon is ascribed to a sort of electric convection, the superficial electrified layer of fluid carrying its charge with it as it slides over the walls of the channels. In the case of a straight uniform tube, for instance, there is in this way a transfer of positive electricity along the walls, from the near to the farther end, which is compensated, if no other path is open, by conduction backwards through the column of liquid in the tube. If the tube be of varying section there will be a tendency also to convergence of positive or negative electricity by convection at intermediate points, and a consequent establishment of 'sources' and 'sinks' as regards the conducting mass of fluid in the interior.

Taking the case of a tube of circular section, through which fluid is forced by an excess of pressure P, and using the same notation as in § 2, we find by the ordinary theory of Poiseuille's experiments

$$u = \frac{P}{4\mu L}(R^2 - r^2 + 2\mu R/\beta) \quad . \quad . \quad . \quad . \quad (26)$$

Hence the total quantity of electricity carried per second along the wall of the tube is

$$2\pi R\rho \,.\, u_R = \frac{\pi R^2}{\beta L} \cdot \rho.$$

If no other conducting channel is open the electricity thus carried forward will return by ordinary conduction through the column of liquid in the tube. Since the resistance of this column is $\sigma L/\pi R^2$, the difference of potential between the ends of the tube is

$$\frac{P}{\beta} \cdot cE \quad . \quad . \quad . \quad . \quad (27)$$

If E is positive (as it appears to be in most cases) the higher potential is

[1] It is to be noticed that one of Quincke's observations remains unexplained, viz., the fact that in sufficiently wide tubes the direction of motion of particles near the walls varied with the strength of the current.

[2] For references see Wiedemann, *Elektricität*, ii. pp. 153 *et seq.*

at the end towards which the liquid is forced. With the same substitutions as before, this becomes

$$\frac{P}{4\pi\mu} \cdot \frac{l}{d} \cdot E \quad . \quad . \quad . \quad . \qquad (28)$$

differing from von Helmholtz's result by the factor l/d, as in the previous cases.[1]

This result does not involve the dimensions of the tube, and may therefore be surmised, like that contained in (10), to be of much wider application than to the particular form of channel above considered. It may be shown, in fact, that if a liquid is forced by pressure through any system of channels with homogeneous walls, and no external path is provided for the electricity set free at various points of these, the resulting distribution of electric potential is given by

$$\phi = -\frac{\sigma\rho}{\beta} p + \text{const.} \quad . \quad . \quad . \quad . \qquad (29)$$

In the first place it follows from (12) that this value of ϕ satisfies

$$\nabla^2\phi = 0.$$

We have next to take account of the fact that the integral amount ot electricity which, in consequence of the slipping of the superficial film of liquid, crosses the contour of any elementary area dS of the wall is not in general accurately zero, and that each such element dS must be regarded, in relation to the conducting mass of liquid, as a (positive or negative) 'source' of electricity. If the origin be taken in this element, and the axis of z normal to it, the strength of this source is

$$-\rho\left(\frac{du}{dx} + \frac{dv}{dy}\right) dS$$

or

$$\rho \frac{dw}{dz} dS.$$

Now at the origin we have

$$\left.\begin{aligned} w &= 0 \\ u &= l\left(\frac{du}{dz} + \frac{dw}{dx}\right) \\ v &= l\left(\frac{dv}{dz} + \frac{dw}{dy}\right) \end{aligned}\right\} \quad . \quad . \quad . \quad . \qquad (30)$$

and if l be small in comparison with the radii of curvature of the walls, &c., we may neglect the second terms in the brackets.[2] Under the same circumstances we shall also have, approximately,

$$\left.\begin{aligned} \frac{du}{dx} &= l \frac{\quad}{dzdx} \\ \frac{dv}{dy} &= l \frac{d^2v}{dzdy} \end{aligned}\right\} \quad . \quad . \quad . \quad . \qquad (31)$$

[1] Dorn infers from a comparison of his experimental results with von Helmholtz's formula that for water in contact with the glass of his tubes E/D = 3·9, about.

[2] The justification of these and the following approximations is given in the Appendix

so that the expression for the strength of the 'source' becomes

$$-\rho l\left(\frac{d^2u}{dxdz}+\frac{d^2v}{dydz}\right),$$

or

$$\rho l\frac{d^2w}{dz^2}.$$

We may further neglect d^2w/dx^2, d^2w/dy^2 in comparison with d^2w/dz^2, so that the last expression may be written

$$\rho l\nabla^2 w,$$

which equals

$$\frac{\rho l}{\mu}\frac{dp}{dz}$$

by (12). Hence (29) makes

$$\text{source} = -\frac{1}{\sigma}\frac{d\phi}{dz},$$

which is the proper surface condition for ϕ.

5. A similar investigation applies to the electromotive forces called into play by the motion of solid particles through a liquid. This phenomenon, which is in a sense the converse of that discussed in § 3, has been observed by Dorn in the case of grains of sand, or glass beads, descending by gravity through a vertical column of water. For the case of steady motion the formula (29) shows that the top of the column will be at a higher potential than the base by an amount equal to $\sigma\rho/\beta$ times the pressure per unit area of the base due to the solid particles. This pressure is equal to the effective weight (*i.e.*, the gravity *minus* the buoyancy) of the particles vertically over the unit area. In Dorn's experiments the observed excess of potential was in fact positive, in accordance with the general rule that ρ (and therefore E) is positive, but the data are not sufficient for further comparison with theory.

The details of the process may be illustrated by the case of a spherical particle. If r denote the distance from the centre, θ the angular distance from the lowest radius, the stream-function for the relative motion is of the form

$$\Psi=\left(\frac{A}{r}+Br-\tfrac{1}{2}Vr^2\right)\sin^2\theta \qquad . \quad . \quad . \quad (32)$$

where V is the velocity of the sphere. The relative velocity of the fluid over the surface is therefore

$$\Theta=-\frac{1}{r}\frac{d\psi}{dr}=\left(\frac{A}{R^3}-\frac{B}{R}+V\right)\sin^2\theta \qquad . \quad . \quad (33)$$

if R be the radius. In consequence of the slipping, the zone bounded by θ and $\theta+d\theta$ gains electricity at the rate

$$-\rho\frac{d}{d\theta}(2\pi R\sin\theta\,.\,\Theta)d\theta.$$

Dividing by the area $2\pi R^2\sin\theta\,.\,d\theta$ of the zone, we find that each point of the spherical surface is, in regard to the surrounding conducting mass, a source of electricity of strength

$$-\frac{2}{R}\left(\frac{A}{R^3}-\frac{B}{R}+V\right)\rho\cos\theta$$

per unit area. Now

$$\left.\begin{aligned} A/R^3 &= -\tfrac{1}{4}V/(1+3l/R) \\ B/R &= \tfrac{3}{4}V\,(1+2l/R)/(1+3l/R) \end{aligned}\right\} \quad . \quad . \quad (34)^1$$

whence, for the strength of the source,

$$-\frac{3V}{R^2}\,l\rho\cos\theta \quad . \quad . \quad . \quad . \quad . \quad (35)$$

approximately. The corresponding potential at any point of the fluid is therefore of the form

$$\phi = \frac{C\cos\theta}{r^2} + \text{const.} \quad . \quad . \quad . \quad . \quad (36)$$

with the condition that at the surface

$$-\frac{1}{\sigma}\frac{d\phi}{dr} = -\frac{3V}{R^2}l\rho\cos\theta;$$

whence

$$C = -\tfrac{3}{2}\sigma V R l\rho \quad . \quad . \quad . \quad . \quad . \quad . \quad (37)$$

If we neglect the slipping, the hydrodynamical theory gives

$$p = \tfrac{3}{2}\,\mu V R\,.\frac{\cos\theta}{r^2} + \text{const.} \quad . \quad . \quad . \quad . \quad (38)$$

so that the relation (29) is verified.

6. It is to be noticed that a comparison of the results of § 1 with those of § 4 indicates the existence of a Dissipation-Function; and from this point of view the connection between the various classes of phenomena discussed in this paper may be very concisely exhibited. Considering, for instance, the case of a porous diaphragm, and distinguishing the two sides of it by the letters A and B, let P be the excess of pressure, and V that of electric potential, in the fluid on the side A. If U be the quantity of fluid, J that of electricity, which is transferred per second from A to B, then the rate of dissipation of energy is

$$2F = PU + VJ \quad . \quad . \quad . \quad . \quad . \quad (39)$$

Now P and V are obviously linear functions of U and J, say

$$\left.\begin{aligned} P &= KU + \kappa J \\ V &= \lambda U + RJ \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (40)$$

where K is the hydraulic and R the electric resistance of the system of channels. In the case of § 1 we have $P=0$, and therefore

$$U = -\frac{\kappa}{K}J,$$

whilst, in § 2, $U=0$, and therefore

$$P = \kappa J.$$

[1] *Motion of Fluids*, § 185. I take occasion to correct the final result (46) of the article referred to. The dissipation of energy by sliding friction has been overlooked. Allowing for this I now find, in the notation there employed,

$$P = 6\mu a V\,.\,(1+2\mu/\beta a)/(1+3\mu/\beta a).$$

If $\mu/\beta a\ (=l/a)$ be small, this is equal to the resistance which would be experienced by a sphere of radius $a-l$ in the absence of slipping.

Again, in the case of § 4 we have $J = 0$, and therefore

$$V = \lambda U = \frac{\lambda}{K} . P.$$

The results we have obtained show that

$$\kappa = \lambda = -K\sigma\rho/\beta \quad . \quad . \quad . \quad . \quad (41)$$

Hence we have

$$\left.\begin{aligned} P &= \frac{dF}{dU} \\ V &= \frac{dF}{dJ} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (42)$$

where

$$F = \tfrac{1}{2} KU^2 - \frac{K\sigma\rho}{\beta} UJ + \tfrac{1}{2} RJ^2 \quad . \quad . \quad . \quad (43)$$

that is, F possesses the characteristic property of a dissipation-function.[1] If we had been entitled *à priori* to assert the existence of such a function, the laws of the phenomena considered in § 4 could have been deduced from those of § 1.

If the suffixes $_1$ and $_2$ refer to the circumstances of two different experiments we have

$$P_1U_2 + V_1J_2 = P_2U_1 + V_2J_1 \quad . \quad . \quad . \quad (44)$$

In particular if $P_1 = 0$, $J_2 = 0$,

$$\frac{V_2}{P_2} = -\frac{U_1}{J_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (45)$$

as is otherwise evident from (41) and the preceding equations.

I do not know whether experiments on the electric transfusion of liquids through a porous diaphragm, and on the electromotive forces developed by difference of pressure between the two sides, have ever been made with the same apparatus. In any future experiments on these subjects, the testing of the reciprocal relation (45) would be of interest, and would apparently not present any great difficulty.

Appendix.

I give here the proof of certain relations which held between the fluid velocities u, v, w, and their space-derivatives at any point of a rigid boundary. Some of these have been employed in §§ 1 and 4.

Taking the origin on the boundary, and the axis of z along the normal, let the equation to the boundary be

$$z = \tfrac{1}{2}(Ax^2 + 2Bxy + Cy^2) + \tfrac{1}{6}(Fx^3 + 3Gx^2y + 3Hxy^2 + Ky^3) + \quad . \quad . \quad (46)$$

Let us first express the kinematical condition that the velocity in the direction of the normal is zero at all points of the wall. The direction-cosines of the normal at any point (x, y) near the origin are

$$\left.\begin{aligned} &-(Ax + By) - \tfrac{1}{2}(Fx^2 + 2Gxy + Hy^2) \\ &-(Bx + Cy) - \tfrac{1}{2}(Gx^2 + 2Hxy + Ky^2) \\ &1 - \tfrac{1}{2}(Ax + By)^2 - \tfrac{1}{2}(Bx + Cy)^2 \end{aligned}\right\} \quad . \quad . \quad (47)$$

[1] See Rayleigh's *Sound*, i. § 81.

approximately. The condition in question therefore is

$$
\begin{aligned}
&-\{Ax+By+\tfrac{1}{2}(Fx^2+2Gxy+Hy^2)\}\left\{u+\frac{du}{dx}x+\frac{du}{dy}y+\ldots\right\}\\
&-\{Bx+Cy+\tfrac{1}{2}(Gx^2+2Hxy+Ky^2\}\left\{v+\frac{dv}{dx}x+\frac{dv}{dy}y+\ldots\right\}\\
&+\{1-\ldots\}\left\{w+\frac{dw}{dx}x+\frac{dw}{dy}y+\tfrac{1}{2}\frac{dw}{dz}(Ax^2+2Bxy+Cy^2)\right)\\
&\qquad\qquad+\tfrac{1}{2}\left(\frac{d^2w}{dx^2}x^2+2\frac{d^2w}{dxdy}xy+\frac{d^2w}{dy^2}y^2\right)+\Big\}=0,
\end{aligned}
$$

where the symbols u, v, w, &c., denote the values of these quantities at the origin. It follows that

$$w=0,$$

$$\left.\begin{aligned}&\frac{dw}{dx}-Au-Bv=0\\&\frac{dw}{dy}-Bu-Cv=0\end{aligned}\right\}\quad\ldots\ldots\quad(48)$$

$$\left.\begin{aligned}&\frac{d^2w}{dx^2}+A\frac{dw}{dz}-Fu-Gv-2A\frac{du}{dx}-2B\frac{dv}{dx}=0\\&\frac{d^2w}{dxdy}+B\frac{dw}{dz}-Gu-Hv-A\frac{du}{dy}-B\left(\frac{du}{dx}+\frac{dv}{dy}\right)-C\frac{dv}{dx}=0\\&\frac{d^2w}{dy^2}+C\frac{dw}{dz}-Hu-Kv-2B\frac{du}{dy}-2C\frac{dv}{dy}=0\end{aligned}\right\}\quad.\quad(49)$$

Take next the dynamical boundary conditions. At the origin these are [1]

$$\left.\begin{aligned}u&=l\left(\frac{du}{dz}+\frac{dw}{dx}\right)\\v&=l\left(\frac{dv}{dz}+\frac{dw}{dy}\right)\end{aligned}\right\}\quad\ldots\ldots\quad(50)$$

Substituting the values of dw/dx, dw/dy from (48), we see that if we neglect lA, lB, lC in comparison with unity, we have

$$\left.\begin{aligned}u&=l\frac{du}{dz}\\v&=l\frac{dv}{dz}\end{aligned}\right\}\quad\ldots\ldots\quad(51)$$

Hence if q denote the velocity parallel to a tangent line at any point P of the wall, we have at P

$$q=l\frac{dq}{dn}\quad\ldots\ldots\quad(52)$$

or if λ_1, μ_1, ν_1 be the direction-cosines of the normal, and λ_2, μ_2, ν_2 those of the tangent line,

$$\lambda_2u+\mu_2v+\nu_2w=l\left(\lambda_1\frac{d}{dx}+\mu_1\frac{d}{dy}+\nu_1\frac{d}{dz}\right)(\lambda_2u+\mu_2v+\nu_2w)\quad.\quad(53)$$

in which of course λ_2, μ_2, ν_2 are to be treated as constants during the differentiations. Let us apply this to the case when P is any point

[1] We are here considering cases where, as in §§ 4, 5, the electric surface-forces may be neglected, being of the second order.

(x, y) near the origin. The values of λ_1, μ_1, ν_1 for this case have been given in (47), whilst we may write

$$\lambda_2 : \mu_2 : \nu_2 = dx : dy : (Ax + By)dx + (Bx + Cy)dy + \ldots$$

Substituting in (53) and equating coefficients of dx, dy, we find

$$\left.\begin{aligned} u+(Ax+By+\ldots\ldots)w &= l\left\{\lambda_1\frac{du}{dx}+\mu_1\frac{du}{dy}+\nu_1\frac{du}{dz}\right.\\ &\quad\left.+(Ax+By+\ldots\ldots)\left(\lambda_1\frac{dw}{dx}+\mu_1\frac{dw}{dy}+\nu_1\frac{dw}{dz}\right)\right\}\\ v+(Bx+Cy+\ldots\ldots)w &= l\left\{\lambda_1\frac{dv}{dx}+\mu_1\frac{dv}{dy}+\nu_1\frac{dv}{dz}\right.\\ &\quad\left.+(Bx+Cy+\ldots\ldots)\left(\lambda_1\frac{dw}{dx}+\mu_1\frac{dw}{dy}+\nu_1\frac{dw}{dz}\right)\right\} \end{aligned}\right\} \quad . \quad . \quad (54)$$

In these equations u, v, w, &c., denote the values of these quantities at the point (x, y), and must be expanded in terms of x, y. Performing the expansions and equating coefficients of x, y, we get the following four relations:—

$$\left.\begin{aligned} \frac{du}{dx} &= l\left(-A\frac{du}{dx}-B\frac{du}{dy}+\frac{d^2u}{dxdz}+A\frac{dw}{dz}\right)\\ \frac{du}{dy} &= l\left(-B\frac{du}{dx}-C\frac{du}{dy}+\frac{d^2u}{dydz}+B\frac{dw}{dz}\right)\\ \frac{dv}{dx} &= l\left(-A\frac{dv}{dx}-B\frac{dv}{dy}+\frac{d^2v}{dxdz}+B\frac{dw}{dz}\right)\\ \frac{dv}{dy} &= l\left(-B\frac{dv}{dx}-C\frac{dv}{dy}+\frac{d^2v}{dydz}+C\frac{dw}{dz}\right) \end{aligned}\right\} \quad . \quad . \quad (55)$$

If we neglect lA, lB, lC as before, these equations combined with the equation of continuity

$$\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}=0$$

reduce to

$$\left.\begin{aligned} \frac{du}{dx} &= l\frac{d^2u}{dxdz}\\ \frac{du}{dy} &= l\frac{d^2u}{dydz}\\ \frac{dv}{dx} &= l\frac{d^2v}{dxdz}\\ \frac{dv}{dy} &= l\frac{d^2v}{dydz} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (56)$$

If there is no slipping $l=0$, and the preceding equations then show that the following quantities all vanish at the origin—

$$\begin{aligned} &u, \frac{du}{dx}, \frac{du}{dy},\\ &v, \frac{dv}{dx}, \frac{dv}{dy},\\ &w, \frac{dw}{dx}, \frac{dw}{dy}, \frac{dw}{dz}, \frac{d^2w}{dx^2}, \frac{d^2w}{dxdy}, \frac{d^2w}{dy^2}, \end{aligned}$$

the last three quantities vanishing in virtue of (49). We may therefore write in this case—

$$\nabla^2 w = \frac{d^2 w}{dz^2},$$

a result which must also hold good approximately when is not zero, provided it be small in comparison with the other linear magnitudes concerned.

Gold and Silver: their Geological Distribution and their Probable Future Production. By WILLIAM TOPLEY, *F.G.S., Assoc.Inst.C.E., Geological Survey of England and Wales, Recorder of Section C (Geology).*

[A paper prepared at the request of Section F (Economics), and ordered to be printed *in extenso* by the General Committee.]

[PLATES VI., VII., VIII., and IX.]

AMONGST the numerous causes to which the recent depression of trade has been attributed that of variations in the production of the precious metals is on all hands allowed to be of importance. Economists differ as to the extent to which this variation influences prices, but all will allow that it has some influence; many believe that it is entitled to the first consideration.

It is, therefore, of interest to review the sources from which our present supply of gold and silver is obtained, and to ascertain (if possible) what is likely to be the supply in the near future.

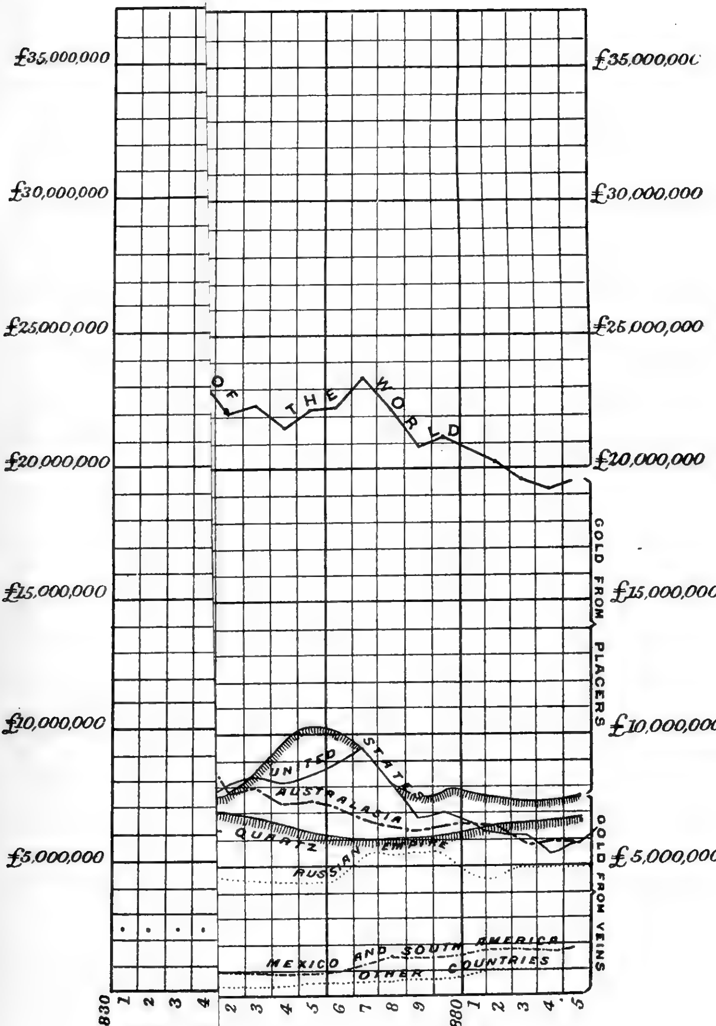
Of late years the production of gold has declined. Is it likely that this decline will continue? If so, will it be rapid or gradual; or may there be periods of oscillation in an average gradual decline? Again, is it probable that the future production of gold will be chiefly from the old goldfields; or are these, as some believe, rapidly becoming exhausted, and must we look elsewhere?

As regards silver, for many years past there has been an increased annual production and a corresponding fall in value. This fall in the value of silver bears hardly upon countries where silver is the only standard of currency, and is especially disastrous in India. The question as to the probable future supply of this metal is therefore only second in importance to that concerning gold.

Questions of this wide character cannot adequately be treated in a short paper. All that I can hope to do, and all that is expected of me, is to treat the matter in general terms; to show where, and to some extent why, the supplies of the precious metals have varied in amount, and to indicate, if possible, where our future supplies may be looked for.

In place of long tables of figures, giving the yield of different countries, I have constructed diagrams. These have the advantage of presenting the general results at a glance, and of enabling us readily to compare one country, or one set of figures, with another. It may be objected that these diagrams do not give exact data; that the produce cannot be read off to within a few hundred thousand pounds. To this objection it is sufficient to reply that the pretended accuracy of figures given in published tabular statements has but slender foundation. For our Australian colonies and for Nova Scotia the yield of gold is fairly well known.

districts,
er mining;



Spottiswoode

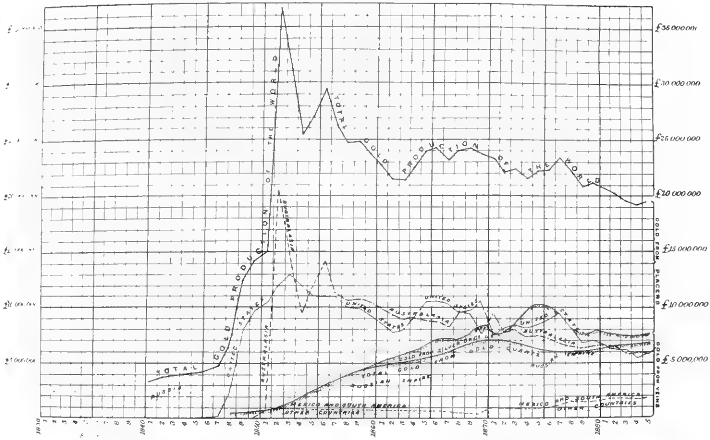
ble Future Production.

Plate VI

TABLE I.

GOLD PRODUCTION OF THE WORLD

Shewing the Total Gold Production, the yield of the Chief Gold producing districts, and (approximately) the Proportion of Gold obtained from Quartz and Placer mining, and from Silver-ores in the United States



Illustrating Mr William Topley's Paper on Gold and Silver: their Geological Distribution and Probable Future Production.

Probably also the gold of the United States, of Russia, and that from metallurgical processes are known with sufficient exactness. But all other figures are simply estimates, often from very loose and insufficient data. The statistics of gold from vein-mining are more easily obtained, and are generally more accurate, than those relating to placer-mining; placer mines being generally spread over large areas, and in the hands of many sets of mining adventurers. The actual returns from mines will likewise be of varying value: where a duty has to be paid the return will be kept low; where a mine has to be puffed its 'returns' will be kept up. Again, in a large number of cases, the only estimate made is of gold exported, and this, even if correct in itself, may not fairly represent the yield of any one year.

Much information upon the production of gold and silver is contained in the 'First Report of the Gold and Silver Commission,' just published, and in the 'Report from the Select Committee on Depreciation of Silver, 1876;' some also in the 'Report of the Royal Commission on Depression of Trade, 1886.' The fullest statistics are those of Dr. Ad. Soetbeer, a second edition of whose book appeared last year.[1] There are also the statistics prepared by the Mint authorities of the United States, and the general statistics collected by Jacob, Del Mar, and others.

Dr. Soetbeer's figures are those generally quoted; but those of Sir Hector Hay are evidently prepared with great care, and should be compared with the former.[2]

Mr. Stewart Pixley submitted a set of figures to the Gold and Silver Commission differing widely from all others. I have placed them on the following table, but have not elsewhere made use of them.

As indicating the uncertainty which hangs over this question, I give here these various estimates of the world's gold production for recent years:—

	Dr. Soetbeer (1886)	Sir H. Hay (1887)	Mr. S. Pixley (1887)
	£	£	£
1876	23,151,000	22,300,000	23,600,000
1877	25,033,000	23,400,000	15,200,000
1878	25,926,000	22,100,000	20,700,000
1879	23,340,000	20,800,000	13,100,000
1880	22,812,000	21,200,000	9,300,000
1881	22,162,000	20,600,000	9,900,000
1882	20,212,000	20,200,000	14,301,000
1883	20,164,000	19,600,000	7,700,000
1884	20,383,000	19,100,000	10,700,000

With variations such as these, it is evidently idle to trouble about fractions of a million in estimating the world's production; and for a similar reason, in considering the future supply, we need pay but little heed to a country where the production is below a quarter of a million, unless it may happen that several increasing countries may together amount to a sum which would have an appreciable effect upon the world's supply.

[1] *Materialien zur Erläuterung und Beurteilung der wirtschaftlichen Edelmetallverhältnisse und der Währungsfrage.* 4to., Berlin, 1866. With an Appendix of Diagrams.

[2] Sir Hector Hay's tables of 1887 give rather larger figures than those published by him in 1876. They have been revised to date by the best authorities obtainable.

It is important to bear in mind that the conditions under which gold has been obtained have varied much in different periods. In the early ages of the world gold was chiefly obtained by forced labour. African slavery was first employed by the Carthaginians in working the gold and silver mines of Spain; and centuries later the Spaniards revived this in working the gold and silver mines of the New World. Moreover, the influx of the precious metals which followed the discovery of Mexico and South America was due to gold already raised, and which was stolen from the natives, and not at first to actual mining by the invaders. The hands of Englishmen have not always been clean in dealing with native races, especially where gold has been concerned; but our record is honour itself when compared with that of those who preceded us in the New World.

Again, the great influxes of gold have come from the discovery and rapid development of alluvial deposits, which, in time, became exhausted; and a steady supply for the future must, for the most part, be sought for in ordinary mining, and in the metallurgical treatment of ores containing small quantities of gold and silver.

Another important point in regard to future supply is the improvement in mining, milling, and metallurgical processes.

In the ordinary methods of alluvial working there are considerable losses, and one source of future supply will be the re-washing of the waste workings of former years. The Californian method of 'Hydraulicking' is the most complete plan for extracting a high percentage of gold from gravels, &c., but this can only be employed where large quantities of water are available at considerable pressure, and where the débris can be disposed of without injury to rivers and cultivated lands.

Mode of Occurrence of Gold.—Gold may be roughly classed under two heads, descriptive of its mode of occurrence:—1. In quartz-veins, cutting through the rocks, though occasionally almost coinciding with the bedding. 2. In detrital beds, derived from the denudation of rocks containing veins of auriferous quartz.

Veins of auriferous quartz rarely occur except in association with eruptive rocks; in the older rocks often with granites, and generally in association with dykes of diabase or diorite. So close is this association that we are led to believe that the eruptive rocks are the means by which the gold has been brought up towards the earth's surface, and thence concentrated by slow aqueous action in the quartz-veins.

That such has been the origin of the gold and silver in the Comstock may now be taken as proved:—'The diabase shows a noteworthy contents in the precious metals, most of which is found in the augite. The decomposed diabase contains about half as much of these metals as the fresh rock. The relative quantities of gold and silver in the fresh and decomposed diabase correspond fairly well with the known composition of the Comstock bullion. The total exposure of diabase is sufficient to account for far more bullion than has been extracted from the mines. . . . Where ore is found in diorite, or in contact with it, it is usually of low grade, and its value is chiefly in gold. The notably productive ore bodies have been found in contact with diabase, and they have yielded by weight about twenty times as much silver as gold.'[1]

[1] G. F. Becker, 'The Comstock Lode,' *2nd Ann. Rep. U.S. Geological Survey*, 1882, p. 309.

The greater part of the more productive auriferous veins are contained within Cambrian or Silurian rocks, generally in argillaceous strata or in alternations of slates and thin sandstones. But some veins are in Archæan rocks (S. America, W. of Lake Superior, and India); some in altered rocks, which are supposed to be of Triassic, Jurassic, or Cretaceous age. These newer rocks occur along mountain chains, where the beds have been greatly disturbed, folded, contorted, and faulted, and where rocks of very different ages occur close together. There are, therefore, frequently difficulties in deciding the exact age of gold-bearing rocks; but at present the evidence appears to be in favour of a great part of the rocks with veins of auriferous quartz along the western side of North and South America being of Secondary age.

The age of the rocks containing the veins does not decide the age of the auriferous veins themselves. Some veins of gold-quartz traversing the Archæan rocks of North America are pre-Silurian, because a conglomerate at the base of the Silurian rocks in Dakota contains gold; and also because in Canada the Silurian limestones rest horizontally upon the denuded edge of the Archæan rocks and of the auriferous quartz-veins. The Geological Survey of Canada is now engaged in mapping these areas; tracing the boundary of the Silurian limestone is important here in limiting the areas within which gold may be looked for. The auriferous quartz-veins of Australia, Nova Scotia, the Ural, and the Transvaal are post-Cambrian or post-Silurian in age, because they traverse Silurian rocks. In New South Wales, Queensland, and Nova Scotia they are, at least in part, pre-Carboniferous, because the lowest Carboniferous conglomerate lies on their edges and contains gold derived from them.

In the Transvaal some of the gold veins are pre-Devonian; they traverse Silurian rocks with intrusive granite and diorite. Resting on the denuded edges of the Silurian rocks, and at the base of beds believed to be Devonian, is a conglomerate containing gold. The Devonian rocks are themselves traversed by diorite dykes and by auriferous veins.

These general considerations supply a key by which the possible occurrence of gold in quantity, or rather its probable non-occurrence, may be anticipated. Gold occurs chiefly in quartz-veins in Cambro-Silurian rocks, or in rocks of other ages which have been, to some extent, altered from their original condition of soft sediment; but, as a rule, only where these rocks have been invaded by intrusive masses of igneous rocks—sometimes granite, but chiefly diorite and diabase. In ordinary fossiliferous Secondary rocks the occurrence of gold veius is unlikely.

In all gold-bearing districts disseminated gold may be expected to occur in rock newer than the auriferous veins; but with rare exceptions it is only where concentrated in gravel that the gold exists in payable quantity.

Gold generally occurs in quartz-veins in the free state; but it is often associated with various metallic sulphides—chiefly iron and copper pyrites. Even here it is probably in a free metallic state, but is so finely divided that its extraction is difficult. All vein-gold is subject to loss in stamping; but the losses in treating gold which occurs with sulphides are often great. Much gold passes away in a finely divided state in the tailings, and there is a further loss in amalgamation in consequence of the gold not presenting a free metallic surface to the mercury. Then losses sometimes amount to about 70 per cent. of the total gold in the ore; it is frequently from 30 per cent. to 40 per cent. Recent improvements in mining and metal-

lurgy have diminished the rate of loss, and from these improvements an increased yield of gold may be looked for.

Under this head of vein-gold should be classed the gold occurring with the ores of other metals in sufficient quantity to be worth extracting. In much of the silver ore of the Comstock, &c., the gold occurs to about one-third the total value.

Gold is widely distributed in iron pyrites, especially when this occurs in lode-like masses traversing the older rocks. Sometimes it is sufficiently abundant, either alone or in association with other metals, to pay well for extraction. Often, however, it is in too small a quantity to pay by any process at present known.

The pyrites at Rio Tinto contain from 8 to 11 grains of gold, and from $\frac{1}{2}$ oz. to 1 oz. of silver per ton. This ore is essentially iron pyrites with a little copper pyrites. With the exception of small quantities obtained from some of the copper at Swansea, Widnes, and in Germany, this gold is entirely lost; yet Mr. J. H. Collins states that the pyrites raised yearly in the Sierra Morena contains a ton and a half of gold, or a money value of about 150,000*l.*

There are other important mineral masses which must be classed with lodes, but which are extremely irregular in their mode of occurrence, and are very likely to diminish in productiveness in depth. There are the 'Bonanzas,' and similar rich masses of ore, which have yielded such vast quantities of silver and gold in the United States. In the Comstock, which is in many respects an exceptional area, the Bonanzas are enlargements of a quartz-lode along the junction-planes of eruptive rocks. As a matter of experience, it is found that these become less frequent and important at great depths.

Of different origin from these Bonanzas, but resembling them in containing large quantities of ore, are the chambers or pockets in calcareous rocks from which the greater part of the silver of the United States is now obtained. These are produced in the first instance by the action of atmospheric water dissolving away the limestone; into the hollows thus formed metallic ores have been subsequently introduced. Such chambers will therefore be unlikely to occur below the level to which surface waters have circulated. Sometimes, as in Nevada and Utah, there is no special relation between the country rock and the metallic contents of these chambers; but in other places, as at Leadville, in Colorado, the ores only occur where the limestone is overlain by eruptive rock.

The important bearing of these considerations on our present subject is this, that although it is not unlikely that great and irregular masses of rich silver or silver-lead ores may be again discovered, which may even for a time rival the past productiveness of the United States, yet it is improbable that any such rich districts will continue to be productive for a long period of time.

The opinion held in the early days of Californian mining, that lodes of gold-quartz diminish in production in depth, has been abundantly disproved. All lodes vary in productiveness in different places, and when in working downwards the lodes became impoverished, the workings were abandoned, and the miners transferred their energies to other lodes at the surface. But it is now known that such impoverishment is in most cases only local. If the lode be followed it generally regains its average productiveness. At the Adelong mine, New South Wales, payable quartz is raised from a depth of 1,030 feet. But it is in Victoria that the

deepest Australian mines are found. In the Sandhurst district there are twenty-nine shafts over 600 feet deep, twenty-three over 1,000 feet, two over 2,000. The deepest is the Magdala mine (Ararat), the shaft of which is 2,409 feet deep.

A lode of the same average productiveness, however, may pay well in the upper part, but may prove unremunerative in the lower part, the actual yield of gold remaining the same. The general working expenses are far less for shallow mines than for deep mines. The lode is decomposed near the surface, and is more easily worked; the sulphides are also decomposed and the gold set free. In deep mines the sulphides are not decomposed, and there is an increased loss in stamping and amalgamating.

The second great division under which native gold may be classed is that of alluvial deposits, derived from the waste of rocks containing auriferous veins. The old conglomerates already referred to belong to this class; but their interest is scientific rather than practical, because they are too limited in extent to yield much gold, although generally worked for the metal where they occur.

The great alluvial gold deposits of the world are of newer Tertiary age. The older beds of California and Victoria are believed to be of about the age of our English Crag; but the evidence for this is by no means conclusive, and they may be of later date. Their great antiquity, however, is proved by—1. Their vast extent and thickness; 2. The great sheets of volcanic rock which cover them; 3. The enormous denudation which the gravels and the overlying sheets of basalt have undergone.

The modern alluvial deposits have been derived from the waste of these old Pleiocene (?) deposits; the gold has thus undergone a second concentration, and the gravels are often proportionally enriched.

Alluvial deposits have hitherto yielded at least nine-tenths of the world's gold; in old times the proportion was higher. The enormous developments of gold-mining within short spaces of time, as in California and Victoria in 1849–52, were entirely due to alluvial mining.

In Russia, Siberia, and British Columbia almost the whole of the gold now produced is alluvial; but in Australia, the United States, and in South America vein-mining is increasing as the alluvial deposits are becoming exhausted.

United States.—Previous to the discovery of gold in California gold was produced in the United States in Georgia, North and South Carolina, Tennessee, Alabama, and Virginia: the total production of these States from 1804 to 1850 is estimated at $15,172,300, Georgia and North Carolina each producing over $6,000,000.

Before 1871 California stood at the head of the States in its output of the precious metals, but from 1871 to 1879 this place was taken by Nevada, in consequence of the immense development of mining in the Comstock area. In 1880 (census year) Nevada fell to the third place, having been passed again by California and also by Colorado, which then ranked first. In 1884 Nevada fell to the fourth place, having then been just passed by Montana, Colorado keeping its place at the top of the list. In 1885 the produce of Montana went rapidly ahead, whilst that of Nevada remained stationary.

The occurrence of gold in California was known to the Spanish Jesuit missionaries and to others, but it was not worked till 1848. So rapidly were the placers developed that in 1849 the production was 8,000,000*l.*, and in 1853 it rose to 13,000,000*l.* Gold-mining began in Oregon in

1852; Arizona in 1858; Colorado in 1859; Idaho and Montana in 1860.

The chief gold-producing States after California are Nevada, Dakota, and Colorado. But up to the year 1880 California produced 50 per cent. of the gold of the United States, and $71\frac{1}{2}$ per cent. of that obtained from placer mines; and even in 1885 it produced 40 per cent. of the total amount of gold obtained.

The following table gives the relative importance of the chief gold-producing States during the census year ending May 31, 1880:—

Range	Total value of gold in dollars[1]	Percentage production in relation to each State		Percentage production in relation to total production of the United States		
		Placer gold	Vein gold	Placer	Vein	Total
California	17,150,954 –	50·03	49·97	71·47	40·09	51·38
Nevada	4,888,247 –	1·02	98·98	0·41	22·64	14·64
Dakota	3,305,846	1·54	98·46	0·42	15·23	9·90
Colorado	2,699,900 +	3·77	96·23	0·85	12·16	8·09
Montana	1,805,764 +	64·40	35·60	9·68	3·01	5·41
Idaho	1,479,655 +	59·42	40·58	7·32	2·81	4·43
Oregon	1,097,700 –	84·39	15·61	7·75	0·80	3·29
Total	32,428,066	36·28	63·72	97·90	96·74	97·14
Other States	951,597	25·54	74·46	2·10	3·26	2·86
Total	33,379,663	35·97	64·03	100·00	100·00	100·00

Since 1880 *California* has decreased to $12,700,000, chiefly in consequence of repressive legislation as regards hydraulic mining. This decrease would be far greater were it not that quartz-mining has much developed. The Bodie district, in Mono county, for some years gave the chief supply of quartz gold; but this has fallen off in yield, and the supplies now largely come from districts further to the north-west.

The gold yield of California has oscillated in past years from causes unconnected with its own resources. In 1857 there was a rush to Fraser river, in British Columbia; in 1863 a great rush took place to Nevada, when from 15,000 to 20,000 people left the State. These variations in Californian produce are plainly seen in the total production of the country.

The great development of placer gold-mining in California was due to the introduction of 'sluicing,' or washing the gravel in trenches cut in the solid rock below. By this method deeper and poorer gravels could be worked than by the older Californian methods.

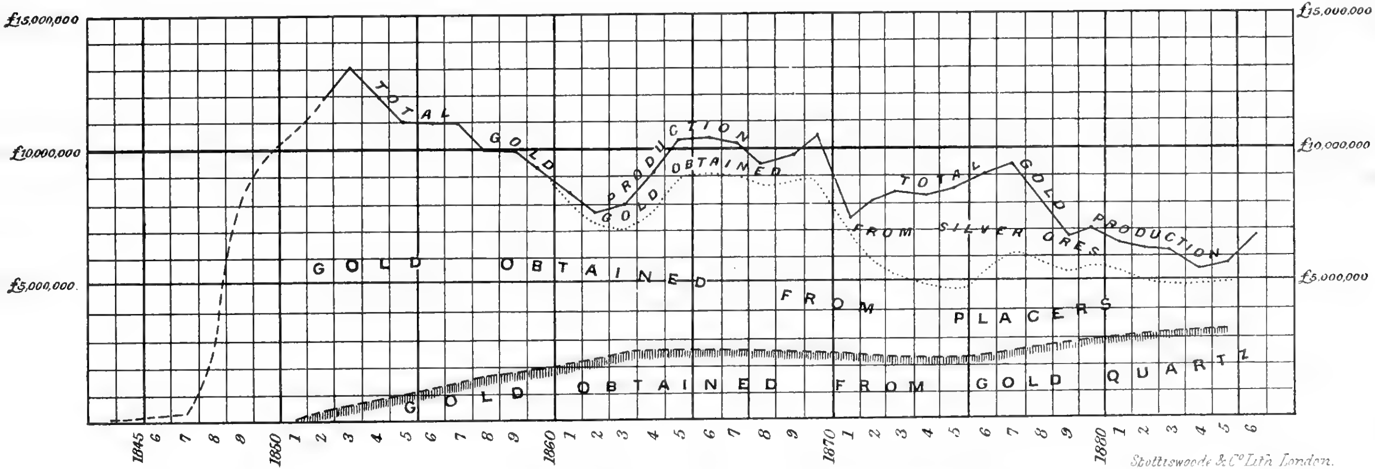
Sluicing, however, is no modern invention; it was employed by the Romans. In 1852 the system known as 'hydraulicking' was introduced, in which the gravel is worked by a stream of water forced against it under pressure. By this system a great part of the Californian gravels was worked up to January 1884. For years before that date there had been constant disputes and litigations between the miners, the farmers, and the owners of streams, because gold-working generally, but hydraulicking especially, had ruined large areas of land, had choked or diverted the

[1] Those marked + have since increased in yield; those marked – have decreased Dakota remains practically unchanged.

TABLE II.

GOLD PRODUCTION OF THE UNITED STATES

Shewing the Total Gold Production; the Gold obtained from Silver Ores; and (approximately) the Gold obtained from Placers and from Gold-Quartz Veins



Spottiswoode & Co. Lith. London.

Illustrating Mr. William Topley's Paper on Gold and Silver: their Geological Distribution and Probable Future Production.

streams, and had largely interfered with the channels of the navigable rivers. In January 1884 the famous lawsuit of Edward Woodruff *v.* The North Bloomfield Gravel Mining Company and six others was decided by the U.S. Circuit Court. The decision prohibited the defendants from 'discharging or dumping into the Yuba river, or into any of its forks or branches . . . any of the tailings, bowlders, cobble-stones, gravel, sand, clay, débris, or refuse matter from any of the tracts of mineral land mentioned in the complaint, and also from causing or suffering to flow into said rivers, creeks, or tributary streams aforesaid therefrom any of the tailings, bowlders, cobble-stones, gravel, sand, clay, or refuse matter resulting or arising from mining thereon. And also from allowing others to use the water supply of said several mines or mining claims, or any part thereof, for the purpose of washing into said rivers and streams any earth, rocks, bowlders, clay, sand, or solid material contained in any placer or gravel ground or mine.'[1]

This decree is sufficiently clear and definite, and from it there has been no appeal. As it stands, it practically puts a stop to systematic hydraulic mining in the basin of the Sacramento and San Joaquin.

The problem which engineers have to solve is whether means can be adopted for impounding the débris at the mines, and so preventing it fouling the streams. Various methods of doing this are under discussion, and upon their success depends the future of Californian hydraulic mining. The decree reserves to the court the power to modify or suspend the injunction 'upon any showing which the court may deem sufficient that the conditions have been so changed that the discharge of such mining débris . . . may be resumed or otherwise conducted so as not to create . . . or continue the nuisance complained of, or a nuisance of similar character.'

Official estimates widely differ as to the amount of material carried into the rivers by hydraulic mining. In the lower Sacramento basin, as a whole, the estimates for the year 1880 were $38\frac{1}{2}$ and $53\frac{1}{3}$ million cubic yards. In the Yuba river, to which the lawsuit especially referred, the estimates were 19 and $22\frac{1}{3}$ million cubic yards.

The area affected by the mining débris was 43,546 acres, and the depreciation in value was estimated at $2,597,634. This district has yielded about $600,000,000 in gold.

The amount of capital invested in hydraulic mining in California is estimated at $100,000,000; the amount of payable auriferous gravel in the area covered by the injunction, and therefore closed, is estimated at 400,000,000 cubic yards.

There are some cases in which hydraulic mining is said to be a benefit to the lands lower down, by raising the level of the stream-beds, and therefore of the sub-surface waters; but in the vast majority of cases it is otherwise.

So far as the United States are concerned, it is only in California that legal restrictions of placer mining seriously affect the production of gold. It may hereafter do so in Oregon and Washington. But in many districts, as population increases and as interests other than mining become important, similar inconvenience will be felt, and doubtless with similar results.

[1] See A. J. Bowie, 'Mining Débris in California Rivers,' *Trans. Tech. Soc. Pacific Coast*, vol. iv. Feb. and March 1887, from which the foregoing information on this subject is taken.

It is fortunate for the future of Californian mining that much placer gold is obtained by 'deep mining'—carrying levels at the bottom of the gravel beds, which often lie under a great thickness of lava. This process, however, is less productive of gold; it can only be profitably employed where the drift is deep and covered with volcanic rock, and where the rich ground is always at the bottom.

'The results of actual practice in Nevada county and elsewhere demonstrate that hydraulic mining, compared with drifting, employs twice the number of men and extracts four to six times the amount of gold per lineal foot of channel. The yield of the North Bloomfield Channel by drifting has been $150 per lineal foot of channel, while hydraulicking the entire deposit in this locality has given a yield of $750 dollars per foot' (Bowie, 'Hydraulic Mining,' p. 86).

The injunction against hydraulic mining applies only to the central counties of California, and in other parts it is carried on as usual. In the north-western part of the State it has of late years been developed; here the rivers flow direct to the sea through deep cañons, and hydraulicking does not harm the streams nor interfere with agriculture.

Colorado has increased from $2,700,000 in 1880 to $4,200,000 in 1885; this increase is mainly due to quartz-mining. The yield of gold in Montana has nearly doubled since 1880, the figures being in 1880 $1,805,764, in 1885 $3,300,000. Here, again, the increase has been mainly from quartz-mining, aided by an increased yield of silver containing some gold. In 1880, 64½ per cent. of Montana gold was from placers; in 1884 only 37 per cent. on a largely increased yield.

1880			1884		
Placer	Vein	Total	Placer	Quartz	Total
$1,162,908	$742,856	$1,805,764	$800,000	$1,370,000	$2,170,000

There was a great rush to the Montana placers in 1862, some of the richest deposits in the world being then worked here; since 1862 over $150,000,000 of placer gold has been produced in this State.

Nevada, which once stood so high in gold produce in consequence of the Comstock,[1] fell in yield of gold to $4,888,247 in 1880, and to $2,000,000 in 1882. This was the lowest yield. It increased to $3,500,000 in 1884. The silver production of the State has continued to decline; very little placer gold is raised (only 1 per cent. in 1881), so that the increase is due to gold-vein mining.

Dakota is remarkably steady in its yield of gold, almost the whole of it coming from quartz veins in the Black Hill district, the placer gold being only 2 per cent. of the whole, and the silver produce practically *nil.*

Dakota is perhaps typical of the future gold-mining industry in the United States. Crushing and amalgamating processes are here carried to great perfection, so that low-grade ores are worked, and a large percentage of the gold value obtained. The average yield of the lodes is only $4 per ton; but ore of only $2 per ton is worked at a profit, the expenses of mining and milling being less than $1 per ton.

Oregon declined in yield of gold from $1,097,700 in 1880 to $660,000 in 1883 and 1884; it increased to $800,000 in 1885. The greater part of this is from placer mines, vein-mining having been as yet but slightly

[1] Mr. Del Mar estimates $18,002,906 gold and $20,570,078 silver from the Comstock in 1876. The total yield from 1859 to 1880 was about $140,000,000 gold and $175 000,000 silver.

developed. It is believed that the production of Oregon is underestimated.

Idaho varies very little in its production of gold, but has somewhat increased in silver. About 60 per cent. of its gold was from placers in 1880, probably rather less than this now.

In *New Mexico* the yield of gold increased from $49,354 in 1880 to $300,000 in 1884, and to $800,000 in 1885; the silver produce has likewise increased, but not in the same proportion. No record of placer workings could be collected during the census year, and it was believed that the amount of gold so obtained was very small. Rich placers were, however, known to exist, and have since been worked. The increase is therefore largely due to this cause.

Arizona, which produced only $212,000 in gold in 1880, increased this to over $1,000,000 in 1881 and 1882; but the yield afterwards fell, and was only $800,000 in 1885. Only 14 per cent. of the yield in 1880 was from placers; the proportion must be considerably less now, the developments of late years having been chiefly in vein-mining.

The remaining States call for no special remark, their total yield of gold in 1885 having been only $1,020,000. Utah ($120,000 in 1885) is interesting from its steady yield of gold, over 90 per cent. of it being from veins.

The general result of this inquiry is to establish the important fact that so far as the United States are concerned the gold supply is steadying, with a slight tendency to increase; we may expect this steady yield to continue, because it is due in an increasing proportion to vein-mining. Placer-mining yielded 36 per cent. of the gold in 1880; only about 30 per cent. in 1885.

Mr. A. Williams in his 'First Report on the Mineral Resources of the United States' (1882) makes the following remarks on the probable future production of the United States; remarks which the succeeding four years have well justified:—'From the foregoing figures [statistics of production] the general deduction may be drawn that the annual precious metal output of the United States during recent years may be stated at between $70,000,000 and $80,000,000, coining value, and that the fluctuations in the proportional amounts of gold and silver are greater than those of the total product. It is also safe to assume that this rate of production will be maintained for some time to come, and that the probability of a slight increase is greater than that of a decline. Experience has shown that old localities become exhausted, or fall off in their rate of production; new localities are developed which fully take their place; and that the general result is therefore nearly uniform as compared year by year. By the time the country has been thoroughly explored for gold and silver deposits—a time which may be considered as indefinitely remote—the facilities for mining and working the ores will undoubtedly be such as to enable systematic and permanent development to be maintained in places and with ores which at present could not be profitable.'

Victoria.—Gold was discovered in Victoria in 1849. It was re-discovered in 1851. There was then a rush to the alluvial workings, and the yield suddenly rose from about 200,000 oz. in three months of 1851 to 2,286,000 oz. in 1882; the maximum yield in 1856 was 3,053,744 oz. The total yield of Victoria up to the end of 1885 is estimated at 53,750,000 oz., valued at 214,000,000*l.*, or an average of 4*l.* per oz.

In the early days of gold-mining in Victoria almost the whole yield was from placers. The relative proportions of quartz and placer gold is not known before 1868; in that year the amounts raised were 1,087,502 oz. of placer gold, and 597,416 oz. of quartz gold. From this date the yield of alluvial gold steadily fell to 1878, when only 264,453 oz. were raised, or one-fourth of that raised in 1868.

Alluvial and vein gold were about equal in 1871. The maximum quantity of vein gold was raised in 1872; the minimum quantity in 1879. For the last four years the average proportions have been about 40 per cent. alluvial gold and 60 per cent. vein gold, and these figures fairly represent the proportions for the whole of Australasia in 1883; but the rapid increase of vein gold in Queensland is now increasing the percentage from that source. From the great importance of Victoria it may be as well more fully to tabulate the facts just given:—

	Alluvial Gold	Quartz Gold		Total Value
	oz.	oz.	per cent.	£
1856	—	—	—	12,214,576
1868	1,087,502	597,416	35·5	6,739,672
1871	698,190	670,752	49·7	5,475,768
1872	639,551	691,826	52·0	5,325,508
1878	264,453	493,587	64·7	3,032,160
1879	293,310	465,637	61·5	3,035,788
1882	352,078	512,532	59·3	3,458,440
1884	307,533	471,085	60·6	3,114,472
1885	—	—	—	2,940,872

The Ballarat district makes the greatest return, producing about one-third of the total yield of Victoria, 64 per cent. of its gold being alluvial; the Sandhurst district comes next, producing one-fourth of the total gold, but only 3 per cent. of its yield is alluvial. The other districts stand thus in relative importance (the percentage of *alluvial* gold in each being also roughly stated):—Castlemaine (34); Maryborough (75); Beechworth (62); Ararat (61).

The rapid development of gold-mining in Victoria and its sustained importance were due to working the shallow and rich alluvial deposits; but these became exhausted, and the produce had to be raised from the deep placers, often underlying a great thickness of basalt. Many of these 'deep leads' are now being worked at 400 and 500 feet below the surface.

'Tens of thousands of pounds are frequently expended before the deep alluvial mines become remunerative, and sometimes after all failure is encountered; but, nevertheless, successes have, in the main, counterbalanced the failures, and increasing experience tends to lessen the risk of the latter. There are still hundreds of miles in length of unworked leads which are likely to reward future enterprise. No great discovery in shallow ground has been made for the last ten years, nor can such be now expected, as no large area of possibly auriferous shallow country remains untried.'[1]

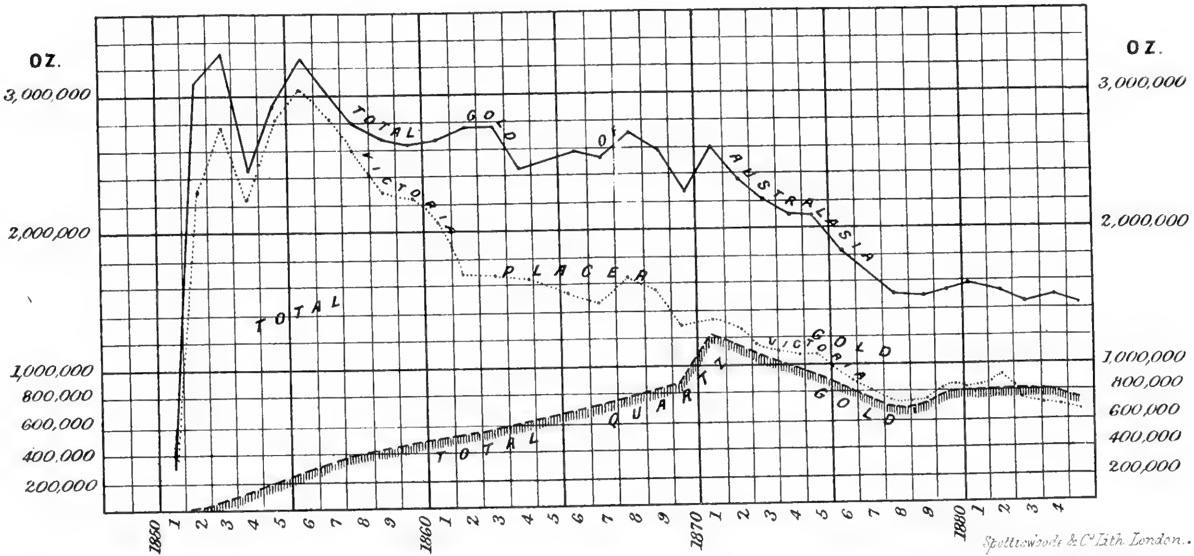
Queensland is, next to Victoria, the most important British gold-producing colony, and it is of especial interest, because the yield of gold is now increasing. In 1867 the yield was under 50,000 oz., in 1868 it rose to 165,000 oz., varied till 1873 (195,000 oz.), and then suddenly rose

[1] *Illustrated Handbook of Victoria*, Col. and Ind. Exhib. 1886, pp. 80, 81.

TABLE III.

GOLD PRODUCTION OF AUSTRALASIA

Shewing the Total Gold Production (in Ounces), the Gold obtained from Placers and from Gold Quartz (approximately) and the Gold Production of Victoria.



Spottiswoode & Co. Lith. London.

Illustrating Mr. William Topley's Paper on Gold and Silver: their Geological Distribution and Probable Future Production.

to 375,000 oz. in 1874, attaining to its maximum of 391,515 oz. in 1875. This sudden rise was due to the rush to the Palmer goldfield and to the rich alluvial ground there worked. The yield fell gradually to 212,783 oz. in 1883; it rose to 307,804 oz. in 1884, and to 310,941 oz. in 1885.

Queensland is now essentially a quartz goldfield. In 1880 the Palmer and other alluvial districts had declined in yield; that from quartz had increased; so that about 65 per cent. of the total yield was in that year quartz gold.

In 1885 the Charters Towers and Cape River goldfield alone produced 43·6 per cent. of the total yield, the Gympie goldfield 28·8 per cent.: these are now almost entirely quartz fields.

The Charters Towers field is especially important. In 1883 its yield was 69,555 oz.; in 1884, 109,335 oz.; and in 1885, 134,650 oz. The amount of gold in the quartz is also increasing as the veins are followed in depth. In the earlier days of mining it was from $1\frac{1}{2}$ oz. to $1\frac{3}{4}$ oz. per ton; it is now close upon 2 oz.

Queensland is also remarkable for the Mt. Morgan goldfield, where the gold occurs impregnating a mass of ferruginous rock, and an iron-stained siliceous sinter, which, with the gold, is supposed to have been deposited by geyserian action. The mass is worked as an open quarry. It contains on an average 7 oz. of gold per ton; the hæmatite contains $3\frac{1}{4}$ oz.; the sinter $10\frac{1}{2}$ oz.; but only about one-half of the gold present can be extracted. The tailings are stored for future treatment. The Mt. Morgan gold is the purest known, its value being 4*l.* 4*s.* 8*d.* per oz. Its fineness is 997, the rest is copper, with a little iron. In all other native gold silver is the chief accompaniment, but in the Mt. Morgan gold there is only a very minute trace. The gold from Mt. Morgan does not figure in the Queensland official returns, it being sent direct to the mint at Sydney.

In *New South Wales* gold was worked in 1851, 144,120 oz. having been raised in that year. This colony reached its maximum the next year (1852), when 818,751 oz. were produced. The yield fell to 171,367 oz. in 1855; in 1858 it rose to 286,798 oz. From that date to the end of 1875 it oscillated much, the greatest amount being 640,622 oz. in 1862, the least being 240,858 oz. in 1870, and 230,883 oz. in 1875. Since 1875 the yield has much decreased, and was only 103,736 oz. in 1885.

The decline from 1884 to 1885 (3,453 oz.) is attributed in the official report 'wholly or mainly to the drought.' It is also stated that some amendments to the Mining Act were made in 1884, which it is hoped will lead to the reworking of some of the abandoned mines, which, it is thought, may prove remunerative if worked on a large scale with system and economy.

The average yield per ton of quartz raised was 1 oz. 12 gr. in 1885, as compared with 14 dwt. 10 gr. in 1884. This was due to the improved quality of the quartz raised in the southern and New England districts. As the average yield per ton was greater in 1885 than in 1884, whilst the total amount of gold produced was less, it follows that the amount of quartz raised was very much less; in fact, it was little more than one-half; indicating a more rapid fall in quartz-mining than is apparent in the returns generally quoted.

In 1880 about 29 per cent. of New South Wales gold was from quartz

veins; in 1882 about 25 per cent. The average value of New South Wales gold has been 3*l.* 14*s.* 6*d.* per oz.

It is probable that the future importance of New South Wales as regards the precious metals will depend largely upon its silver. The ores chiefly occur towards the northern and western parts of the colony, the latter being that most recently becoming of importance. All accounts agree in the richness of the ores and in the extent of the argentiferous area.

The following figures show the recent production:—

	Silver		Silver-lead Ore			Total Value
	Oz.	Value	Tons	Cwt.	Value	
		£			£	£
1881	57,254	13,026	52	14	1,625	14,651
1882	38,618	9,024	11	19	360	9,384
1883	77,065	16,488	136	4	2,075	18,563
1884	93,660	19,780	9,167	11	241,940	261,720
1885	794,174	159,187	2,286	0	107,626	266,813

South Australia has never yielded much gold. But there was a fairly steady rise to its maximum of 21,454 oz. in 1884,[1] then a sudden fall in 1885 to 4,694 oz., its lowest yield since 1873. The average value of South Australian gold is 3*l.* 9*s.* 4*d.* per oz.

It is known that there are unworked alluvial deposits and reefs in the northern territory, which the new railway may open up, and which may for a time somewhat increase the yield of gold.

The first return for *New Zealand* was in 1857, when 10,437 oz. were obtained; the yield fell to 4,538 oz. in 1860, and then rapidly rose to its maximum of 735,376 oz. in 1866.[2] Since that date there was a fairly steady decline to 1884, when the yield was 229,946 oz., which increased to 233,068 oz. in 1885. The average value of New Zealand gold is 3*l.* 18*s.* 4*d.* per oz.

The yield of gold in New Zealand has remained much more steady than in the other Australian colonies, with the exception of Queensland. It now yields only a little less than one-third of its maximum, whereas Victoria now yields less than one-fourth and New South Wales less than one-sixth.

Almost one-half of the New Zealand gold is now obtained from quartz, 111,432 oz. having been so obtained in 1885; an increase of 23,000 oz. over the quartz gold of 1884.

From this fact, and from the known occurrence of unworked reefs, there is reason to hope that the yield from quartz-veins may continue steady even if it does not increase.

Gold-mining in New Zealand is interesting from the application of

[1] These figures give the amount of gold received at the various Australian mints from South Australia, and possibly are under-estimates.

[2] I take these figures and many others relating to Australasia from the 16*th Ann. Rep. of the Deputy Master of the Mint* (1886), giving a complete table of Australian produce to the end of 1884. Dr. Hector's diagrams, published in the 3rd edition of his *Handbook of New Zealand*, 1883, show the maximum yield in 1871. These diagrams distinguish the alluvial and the quartz gold in each of the four districts into which New Zealand is divided.

electricity to quartz-crushing. At the Phœnix Quartz-mining Company, Otago, water power is used to drive two Brush dynamos, each transmitting 36 horse-power to the stamps two miles away. This is said to work well, and if fully successful here will doubtless be turned to good and profitable account in other places where the water power is not conveniently situated for crushing.[1]

In *Tasmania* gold was discovered in 1852, and quartz-mining began in 1859; but the yield must have been small, as in 1866 the production was only 348 oz. It varied up to 11,107 oz. in 1876, falling to 5,777 oz. in 1877. The discovery of the Lisle alluvial deposits raised the yield to 25,249 oz. in 1878, which increased to 60,155 oz. in 1879. This was the maximum year. The yield had declined to 41,241 oz. in 1885.

Taken on the average of the twenty years 1866–85, the alluvial gold has been only 33 per cent. of the total amount, the Lisle and West Coast districts (both entirely alluvial) together producing 20 per cent. of the total amount. In 1885 the alluvial gold was only 19 per cent. The average value of Tasmanian gold has been 3*l.* 18*s.* per oz.

The gold yield of Tasmania is small, but is subject to less fluctuation than other goldfields; its present yield is more than two-thirds of its maximum. This steadiness is due to the large proportion of vein gold. Unless the accounts of the newly discovered 'Iron Blow' are grossly exaggerated, we may expect that the yield of vein gold will now increase.

As regards Australasia, the general result may be stated as follows. Although Victoria still holds the first place, and may do so for some years to come, there is some probability of it being deposed from this position of honour in favour of Queensland, the vein gold from which is increasing in amount, and is likely to do so still more. With a probable increase in New Zealand, and much placer gold still unworked in Victoria, it is likely that the total produce of Australia will, for some time to come, not fall below 5,000,000*l.* per year.

A fact of some interest, and not yet explained, is the decrease in the fineness of Australian gold as we pass from south to north, due to the increased amount of silver in it. The same thing occurs in New Zealand. This generalisation, however, does not hold in North Queensland. Apart from the Mt. Morgan deposit, which is remarkably pure and is in every way exceptional, we find that the gold of North Queensland is finer than that in the south of the colony.

Canada.—The chief gold-producing districts are *British Columbia*—almost entirely alluvial, and *Nova Scotia*—almost entirely veins. Alluvial gold has long been worked in Quebec, in the Chaudière valley, but no serious attempt has yet been made to work the quartz veins which are known to exist here in the Silurian rocks. Gold occurs in the gravels of the Saskatchewan, and is apparently most abundant near Edmonton. As no gold has been found in the streams coming from the Rocky Mountains the origin of the gold must be looked for elsewhere; it is supposed to lie in the great drift deposit which forms the prairies, and which has been largely made of the waste of the Archæan rocks to the N. and N.E. Near the Lake of the Woods auriferous quartz veins occur, but only near the contact of the Laurentian granitoid gneiss with intrusive schistose hornblende rocks; bosses of intrusive granite

[1] *Report* [to New Zealand Parliament] *on the Mining Industry of New Zealand,* 1887, p. 83.

occur in the district. Silver occurs in these veins, sometimes in greater proportion by weight than gold.[1]

British Columbia.—Gold is chiefly found in the alluvial beds of the Rocky Mountains, in the Purcell, Selkirk, Gold, and Cariboo ranges, which run parallel to, but west of, the main ridge. The discovery of alluvial gold in the Fraser river drew away many miners from California in 1857–9. In 1860 the Cariboo district was discovered, and this has been the most continuously productive. Up to the end of 1885 about 10,000,000*l.* of gold were produced, three-fifths of which came from the Cariboo district. Good alluvial ground has been found on the Wild Horse creek (Skirmish river of Palliser), derived from the waste of quartzites, schistose rocks, and argillites, with some compact greenstones probably interbedded; the gold is worth 3*l.* 16*s.* per oz. Rich placers have recently been discovered on Granite creek.

Practically the whole of the gold yet produced in British Columbia is alluvial. No doubt some productive gold-bearing veins will be discovered, but it seems unlikely that they will yield a large supply.

The gold statistics of British Columbia are very untrustworthy, as no official records have been kept.[2] The maximum yield was, probably, in 1864 (778,000*l.*); it fell, with various oscillations, to 280,000*l.* in 1881, and then gradually declined to 140,000*l.* in 1885. The fluctuations in yield are partly due to the seasons, heavy floods in the spring being disastrous to placer mining; but the fall is due to the exhaustion of the placers with no compensation in the development of vein-mining. Some revival may be looked for from the systematic adoption of hydraulic mining, as in some places only the sides of the valleys have yet been worked.

British Columbia is placed at a great disadvantage for gold-mining as compared with California. In California the sheets of volcanic rock have preserved large areas of rich placer gravel from denudation; the modern streams have cut their way through these old gravels, enabling them to be mined without great trouble from water, and affording every facility for drift-mining, and, where otherwise convenient, for hydraulic mining. The waste of the old placers has rendered the modern alluvial gravels very rich in gold.

In the Cariboo district of British Columbia the streams have not cut their way through the older placers into the bed rock. From 50 to 150 feet of the richest auriferous gravel lies beneath the stream beds. All the rich placers of the Cariboo have been mined by underground drifting with all the difficulties of water and 'slum' to contend with overhead. At Omineca and Cassiar, lat. 55° to 57°, the auriferous gravel is in perpetually frozen ground; the working season lasts only two months in the year.[3]

Nova Scotia.—It was formerly supposed that the auriferous quartz of Nova Scotia was interstratified with the Lower Silurian (Cambrian) rocks, and that the gold had been derived from the underlying Laurentian rocks. It is now known that this was a mistake; the quartz-veins run in a general way along the lines of bedding, but they cut across the beds, and are certainly of later date.

[1] A. C. Lawson, 'Lake of the Woods Region,' *Geol. Survey of Canada*, Ann. Rep., N.S. i. 1885.

[2] It is believed that a small part of the placer gold from Alaska is carried over the frontier, and is returned as produced in British Columbia.

[3] A. Bowman, *Trans. Amer. Inst. M. E.*, 1887, p. 716.

Practically the whole of the gold of Nova Scotia is raised from quartz-veins; the denudation of the gold-bearing rocks must have produced a vast quantity of alluvial gold, but this is now mainly dispersed over the bed of the Atlantic,[1] although it is likely that some gold may be found beneath the alluvium of the valleys near Halifax. Gold was discovered in 1859; in 1862 over 7,000 oz. was raised, 14,000 oz. in 1863, 20,000 oz. in 1864, and 27,000 oz. in 1867: this was the maximum yield. Since 1871 it has ranged from 11,000 to 16,812 oz., with the exception of one year (1874) when it fell to 9,140 oz. The steady increase of late years is noteworthy:—

Year	Total ounces of gold extracted			Stuff crushed	Yield per ton of 2,000 lbs.	
	oz.	dwt.	gr.	tons	dwt.	gr.
1881	10,756	13	2	15,556	12	20
1882	14,107	3	20	22,081	12	18
1883	15,446	9	23	25,954	10	21
1884	16,059	18	17	25,147	12	18
1885	22,203	12	20	28,890	15	4
1886	23,362	5	13	29,010	16	2

The increase in 1886 as compared with 1885 is chiefly due to the opening of new mines and to the yield in 'unproclaimed' districts; some of the older districts fell off considerably. The gold mainly exists in the free state, and generally in quantities visible to the eye. But the veins also carry sulphides which include a considerable amount of gold. Most of this gold passes into the tailings. 'Assays show that these tailings when concentrated are often rich enough to warrant attempts being made to save the gold; but hitherto no systematic attempts have been made in this direction.'[2]

Although interesting to us the gold of Canada has no great influence on the world's production. In 1864, following the great rush to the Fraser river, British Columbia ranked, after California, with the best of the American States; but it now would take only the tenth place, and Canada, as a whole, would only take the seventh place.

Russia.—The large amount of gold obtained since 1851 from the United States and from Australia leads most people to pay but small heed to Russia as a gold-producing State, but this is a grave mistake. During the few years preceding the great gold discoveries Russia (including Russian Siberia) was the chief gold country of the world; and notwithstanding the great output of other districts the variations in its yield have had a perceptible influence upon the world's production. The maximum yield was, in 1879, 5,942,000*l.*; the yield fell to 4,561,000*l.* in 1882, but rose again the next year, and was 4,980,000*l.* in 1884.

The history of Russia's gold production is shown on Table I.; when compared with the production of the other great gold countries its uniformity is very striking. This is the more remarkable because almost the whole of Russian gold is obtained from placer workings, quartz-

[1] An interesting example of placer of Carboniferous age occurs at Gay's river. This has been worked to a small extent. (H. S. Poole, *Q.J.G.S.* vol. xxxvi. 1880, p. 313).

[2] E. Gilpin, *Report Dep. Mines, Nova Scotia,* &c., 1885

mining being mainly confined to the south-eastern slopes of the Ural Mountains. The reason of this uniformity of yield is the vast area over which the workings extend. The yields of the various districts have varied much, but the average production of the whole is fairly steady.

Since 1829 Siberia has been the chief source of Russian gold. From 1867 to 1874 it yielded from two-thirds to three-fourths of the total amount.

In 1860–67 the Ural district yielded about 20 per cent. of the total production; in 1872 this fell to $17\frac{1}{2}$ per cent., and in 1877 to 16 per cent. Since that date it has still further decreased. The yield of eastern Siberia has risen, and in 1877 amounted to 78 per cent. of the whole.

The modern developments of Russian gold-mining have been in the extreme east, in the basins of the Amur and the Lena; here, as elsewhere in Siberia, entirely in alluvium. Much of the ground is perpetually frozen, and has been so probably since the Glacial period. This frozen condition of the gravels has protected them from denudation; but for this much more would have been swept into the sea by the summer floods. The preservation of the Siberian placers is thus due to frost; those of the Californian and Victorian placers to volcanic action.

The vast extent of unworked placers in Eastern Siberia will yield a steady supply for many years to come. But the older placer workings in other areas will fall off in yield, and therefore it would not be safe to anticipate a yearly increase to the world's annual production from this source. There is one point, however, to be borne in mind. The source of the gold must be in the Altai and in the ranges of mountains to the east. All this is practically unexplored; and we may fairly anticipate the discovery here of quartz veins, which will probably help to keep up the supply of Siberian gold when the yield from the placers declines. Very little is known of the geology of this region, but the existence of Silurian rocks has been proved.

African Gold Coast.—This has long been known as a source of gold, and the amount of the metal thence exported must in the aggregate have been very considerable. There are no means of ascertaining the amounts obtained, and hence the wildest estimates are made.

It has been stated that Western Africa during part of the last century produced over 3,000,000*l.* of gold yearly. Similar estimates have been made for South-eastern Africa during the Portuguese rule. But Dr. Soetbeer's estimate for the whole of Africa is a yearly average of 279,000*l.* from 1701 to 1740, and of 209,250*l.* from 1741 to 1800. It is probable that the yearly production of the whole world during the last century rarely exceeded 3,000,000*l.*, and that only during the maximum period of the Brazilian placers. We need not, however, doubt the existence of rich alluvial tracts in Western Africa, which, after having been drawn upon for centuries by hand labour, may yet for a while yield considerable supplies if systematically worked. There must be numerous auriferous reefs the denudation of which has yielded the gold of the river gravels and of the seashore. Some of these have long been known, and a few partially worked, and from them hereafter a somewhat increased yield for West Africa may be expected.

The quantity of gold exported from the British possessions at the Gold Coast during 1884 is officially stated at 24,994 ounces, valued at 89,981*l.*

South Africa.—No trustworthy data are available for ascertaining the

yield of gold in South Africa, and the accounts of the value of the gold-producing areas are very conflicting. Some look to South Africa as a district which will soon rival California and Victoria; but there is no evidence that such a future is before it. There are numerous reefs of auriferous quartz, some apparently along the bedding of the rocks, others cutting across the bedding: these auriferous veins are associated with intrusive diorites.

No important areas of alluvial gold-bearing gravels are known, although most of the gold obtained up to within the last few years was alluvial. The future of South African gold-mining depends upon quartz veins. The veins yield gold of rather more than average purity and quantity. At present only the richer veins are worked, but with improved methods and machinery much of the poorer ore can be treated, which will increase the total yield whilst reducing the percentage. So far as yet worked, the gold of the veins is mostly free; the losses in working should therefore be less than in most other vein-areas, or than probably will be the case when the veins are followed to the deep.

A steadily increasing yield of gold may be looked for from this area, but, so far as we yet know, not in sufficient amount to be of importance in the general stock of the world. Much of the Transvaal gold passes through Natal; the value thus exported was 6,865*l.* in 1882, and 52,222*l.* in 1885.

India.—Although gold occurs in many parts of India, it is only to the southern part of the peninsula that people look who have great hopes of a large gold supply. Probably these hopes are less high and less generally felt than they were a few years back. There are no deep placers, such as have yielded the vast supplies of Victoria and California; the shallow alluvial deposits, often locally very rich, have been in great part exhausted, and for the future supply of Indian gold we must look to vein-mining. The Wynaad and Mysore are the districts most likely to yield the future supply. In the former the gold is often associated with sulphides, and hence there is much loss in working. In Mysore the gold is more often free. Kolar is supposed to be the district which yielded the chief supply of gold to the native princes in past times, and it gives some promise of supply for the future.[1] But there is no probability that it, or any other part of India, will rise to a high rank as a gold-producing country. Nothing is officially known as to the exact amount of gold produced in India at the present time.

The amount of gold raised in *China* is certainly large, but its value is unknown; Mr. R. Giffen states that the excess of export of gold over import is about 1,000,000*l.* per year. This is important, because, from the absence of statistics, China is not included in Dr. Soetbeer's estimate.

Many of the Asiatic islands, and especially Japan, have in the aggregate yielded a considerable amount of gold, and will probably continue to do so; but from the point of view in which we are now considering the question these areas need not detain us. Here, as in Africa, the reputed production during Portuguese rule is vastly in excess of what, apparently, can be raised now.

South America and Mexico.—It is of some importance to obtain a fairly correct estimate of the yield of South America and Mexico, because it is on all hands allowed to be large. The differences in the

[1] See Professor V. Ball's *Coal, Iron, and Gold Mines of India,* and his lecture to the Geologists' Association, *Mining Journal,* June 12, 1886.

estimates of Sir Hector Hay and Dr. Soetbeer are chiefly due to different figures for these districts, Sir Hector Hay's being much the lower as regards silver, and slightly lower as regards gold.

There is some convenience in classing Mexico with South America, because together they contain the older goldfields of the western hemisphere, the chief source of the precious metals from the discovery of America to the development of the Russian and Siberian goldfields.

The annual yield of gold in the *United States of Columbia* is thus approximately given by Dr. Soetbeer:—

	£		£
1851–1860	483,000	1869–1881	621,000
1860–1863	395,000	1881–1882	798,000
1863–1869	496,000		

It therefore ranks between New South Wales and New Zealand.

Gold occurs here in lodes cutting through rocks of all ages from pre-Cambrian to Cretaceous, and under many varieties of condition and purity.

The rapid development of gold mines in *Venezuela* is shown in the following table:—

	£
1866 to end of 1879	3,080,100
1880	467,100
1881	475,100
1882	554,000
1883	716,600
1884	937,700
1885	688,100
1886	796,800
	7,715,500

Of this amount El Callao alone has produced 4,175,000*l.* Of the gold raised in 1886, 83 per cent. came from this mine. All accounts agree as to the gold resources of Venezuela, but, with the notable exception just mentioned, few of the mines have as yet been successful.

The yield of *French Guiana* averages about 240,000*l.* yearly; this is all alluvial gold. *Dutch Guiana* produced about 70,000*l.* in gold in 1879; gold mining commenced here only in 1875.

Gold is known to occur in *British Guiana*, but very little has been done to work it. Something may be done here when the political questions are in a more settled state.

Brazil yielded a great deal of gold in the last century, when the rich placers were discovered. As these were worked out the yield fell, and the produce now is very largely from quartz-mining. The period of maximum productiveness was from about 1730 to 1750. In some of these years it is supposed that about 5,000,000*l.* of gold were raised; but the average production must have been much below this. It fell to an average of 50,000*l.* from 1800 to 1840; rose to 250,000*l.* or 300,000*l.* between 1840 and 1860, and then rapidly fell; in 1870 and for a short time after it is believed to have fallen to 5,000*l.*[1]

With the development of vein-mines the gold production of Brazil rapidly rose, largely in consequence of the St. John del Rey mines. But of late years it has declined in consequence of a series of misfortunes at these mines. In 1879 the production of the Minas Geraes district was

[1] These figures are from Del Mar, *Hist. of the Precious Metals*, 1880, p. 123.

about 235,000*l.* The yield was estimated at about 155,000*l.* in 1881 and 1882, and at about 132,000*l.* in 1883 and 1884.

The estimates for the total production of gold in Brazil, from the first working of the placers (about 1680) to 1880, give from 145,000,000*l.* (Soetbeer) to 180,000,000*l.* (Del Mar); one-tenth, or less, being from vein-mining. The remaining South American States, including *Peru*, *Bolivia*, and *Chili*, probably produce about 100,000*l.* yearly.

Mexico is chiefly known as the great source of silver, but its gold produce is of some importance.

In 1878 the yield was estimated at 207,000*l.*; it fell to 178,000*l.* in 1881, and rose to 245,000*l.* in 1884. The greater part of this is from veins —chiefly of auriferous quartz, but partly of gold with ores of other metals.

Europe (other than Russia).—It would be of great interest to trace the sources of the gold raised in Europe, and especially to discuss the production in times when Europe was largely dependent upon its own resources for its stock of gold. But this would carry us beyond the limits of our subject. Nor need we stay to describe in detail the production of each country. All the gold-bearing districts of Europe are well known, and there is no likelihood of any increased yield, save to some extent by the improved treatment of ores containing gold in small quantities. The recent increase in the gold of Germany is mainly due to this cause, many low-class sulphuretted ores from Australia being sent there for treatment.

The following are statistics of European gold:—

	1881[1]	1882	1883	1884
	£	£	£	£
Austro-Hungary	248,100	218,000	225,000	220,400
Germany	48,000	52,000	63,000	77,000
Italy	20,000	20,000	20,000	20,000
Turkey	1,025	1,380	1,460	1,460
Sweden	138	2,355	5,200	2,700
	317,263	293,735	314,660	321,560

Silver.—In the centuries immediately preceding the Christian era Spain and Greece yielded much silver. The Carthaginians, and after them the Romans, systematically worked the mines in Spain. The richest mine was that of Bebulo, the modern Guadalcanal, which for a time is supposed to have supplied Hannibal with 300 lbs. of silver per day.[2]

In Greece the richest mines were those of Laurium (argentiferous galena), which M. Cordella, judging from the slags and waste-heaps, believed to have produced about 2,100,000 tons of lead, and over 18,000,000 lbs. of silver.[3]

On the revival of mining in the seventh and eighth centuries the

[1] The French official mineral statistics make a return of gold for France:—4,300*l.* in 1880; 5,356*l.* in 1881. The ores from which it was obtained were probably, in part at least, derived from foreign sources.—J. A. Phillips, *Ore Deposits*, p. 232.

[2] Del Mar, *Hist. of the Precious Metals*, p. 23.

[3] The most interesting instance of re-working old slags and mine-waste is that at Laurium. The slags here contain from $5\frac{1}{2}$ to 14 per cent. of lead, whilst many ancient slags in Spain and Italy contain 25 per cent. From these old Laurium

silver mines of Spain were re-worked by the Arabs. Mines in Germany were opened which, until recently, have continued to yield a good supply. During the six or eight centuries preceding the discovery of America, Spain and Germany yielded the greater part of the silver of Europe.

With the discovery of the New World large supplies of silver were poured into Europe, chiefly from Mexico and Peru. At a later date Chili and Bolivia became great silver-producing countries; from all these a steady supply still comes, and is likely to come.

With the discovery in 1859 of the Comstock, in Nevada, the United States rapidly rose into importance as a silver-producing country. About 1873 the production of the United States equalled that from the older silver areas of Mexico and South America, and afterwards, for a time, exceeded it.

Rich silver-bearing districts were discovered in Colorado, Utah, and Arizona, the yield from which helped to balance the rapid fall in Nevada. But the total production of the United States has of late years only slowly increased, whilst that from Mexico and South America has been steadily and more rapidly rising, so that now the older silver areas of the New World again stand at the head of the list.

Silver is almost entirely obtained from veins or from irregular masses associated with veins. The main exception to this is the silver contained in copper ore, which sometimes is disseminated through bedded rocks, the best example of which is the copper slate of Mansfeld.

The veins may be roughly divided into those of true silver ore, argentiferous lead ore—chiefly galena, and various argentiferous ores of copper. So various in character are the veins, their relation to the enclosing rock, and the nature of the ores, that no useful purpose would be served by touching upon these questions here; they are fully discussed in Phillips's 'Ore Deposits' (1884), to which work those wishing information on the subject should refer.

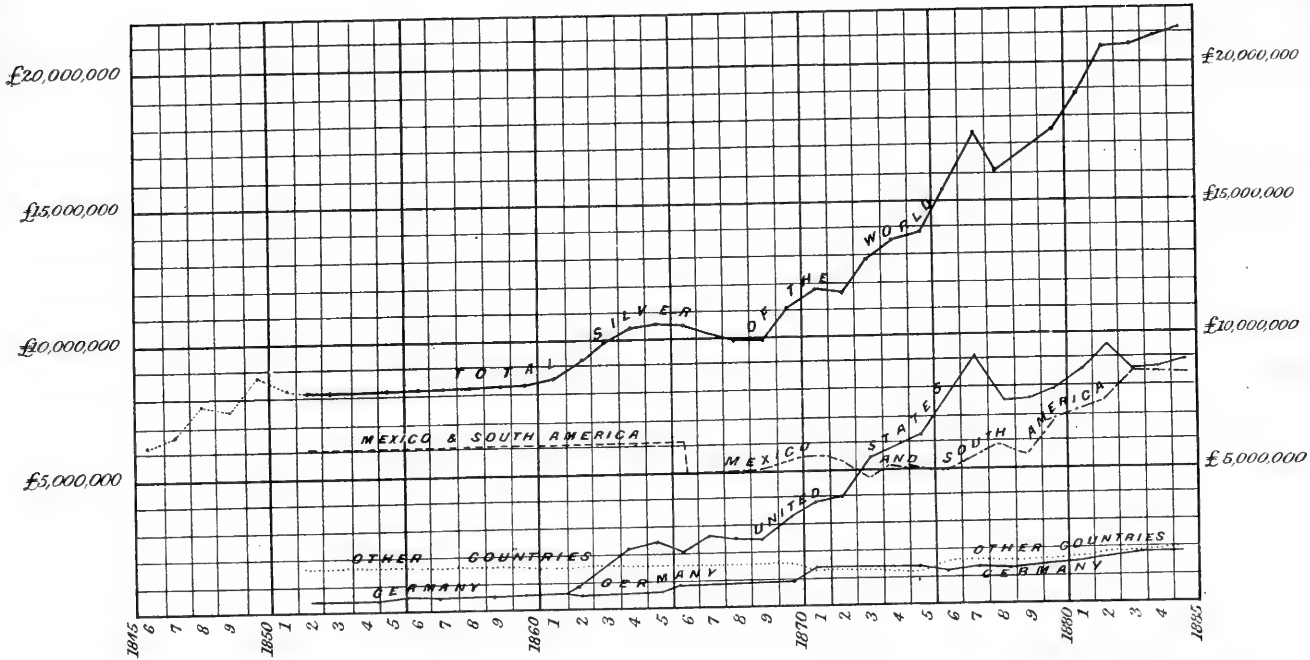
One point, however, is of so much importance to our subject that attention must be especially directed to it—that is, the exceptional nature of many of the great silver deposits of the United States. These have been already briefly referred to, and it was pointed out that whereas lodes often retain their productiveness to indefinite depths, these rich bonanzas and chambers of ore are very irregular in their occurrence, and are unlikely to continue productive to great depths or for long distances.

It is possible that other deposits resembling the Comstock may exist, and may some day be worked; also that other rich deposits like those of Leadville may be found; from which large quantities of silver ore or silver-lead ore may be obtained. But the expectation often expressed that such mines will become common and will flood the world with silver is quite unwarranted. If the United States is to keep at anything like its present production, the discovery of some such rich deposits is needful to balance the loss of those now becoming exhausted; as the mines are deepened the working expenses greatly increase, whilst not unfrequently (unlike the majority of gold-quartz mines) the productiveness of the lode diminishes.

slags and waste-heaps, and also from some ore freshly raised, the production of lead has been from 7,000 to 10,000 tons yearly, with from 8*l.* to 14*l.* of silver per ton of lead. Over 1,000,000*l.* in lead and silver have been produced from the Laurium mines since they were reopened in 1864.

TABLE IV.

SILVER PRODUCTION OF THE WORLD



Illustrating Mr. William Topley's Paper on Gold and Silver: their Geological Distribution and Probable Future Production.

At the time of the Comstock's maximum yield very little silver was obtained in the United States beyond the limits of Nevada; but now there are seven States each producing $3,000,000 and upwards per year; two States each produced over $10,000,000 in 1885.

The following table gives the production for the years 1880–85 in thousands of dollars: 750,= $750,000.[1]

	1880	1881	1882	1883	1884	1885
California	1,151,	750,	845,	1,460,	3,000,	2,500,
Colorado	16,550,	17,160,	16,500,	17,370,	16,000,	15,800,
Nevada	12,430,	7,060,	6,750,	5,430,	5,600,	6,000,
Utah	4,743,	6,400,	6,800,	5,620,	6,800,	6,750,
Montana	2,905,	2,630,	4,370,	6,000,	7,000,	10,060,
Arizona	2,326,	7,300,	7,500,	5,200,	4,500,	3,800,
Idaho	464,	1,300,	2,000,	2,100,	2,720,	3,500,
New Mexico . . .	392,	275,	1,800,	2,845,	3,000,	3,000,
Other States . . .	150,	125,	235,	175,	180,	190,
Total . .	41,111,	43,000,	46,800,	46,200,	48,800,	51,600,

Canada.—The beautiful silver ores from near Lake Superior, exhibited in the Canadian Court of the Colonial and Indian Exhibition, naturally led many people to think highly of this district as a probable source of silver; such expectations have been quite recently revived. Dr. T. Sterry Hunt, to whom the whole district is well known, informs us that, although in places remarkably rich, the lodes are not continuously productive. Many attempts have been made to work them, but without success. Silver Islet, near Port Arthur, has yielded the largest amount of ore. Dr. Selwyn states[2] that this was worked at intervals from 1869 to 1884, and produced a total of about $3,000,000. The lode was followed to the depth of 1,230 feet, and the mine was then abandoned.

Great uncertainty exists as to the actual amount of silver produced in *Mexico and South America*, but on all hands it is allowed to be large. In 1800 these countries gave about 91½ per cent. of the world's production, Mexico alone giving 61½ per cent. In 1850 they gave 82½ per cent.; Mexico, 58½. In 1865, 63 per cent.; Mexico, 42.[3] In 1883, 41¼ per cent.; Mexico, 26. The relative importance of Mexico and South America have, therefore, declined, but their actual output has increased.

The production of silver in *Germany* has steadily increased during the last thirty years, but this is due to the great development of metallurgical works, to which, from all parts, are sent low-grade ores of gold and silver and ores of other metals containing small quantities of these. It is not due to output from the local mines, for silver mining in Germany is generally in a very depressed state. Some Government mines, notably those of the Harz, are kept going at a loss in order to provide employment for the large population dependent upon them.

The silver produce of *Norway* is now valued at about 50,000*l.* per year, which was the average of the years 1834 to 1864. The production in the period here mentioned varied much, the largest returns being

[1] The total production for 1886 is $51,000,000.

[2] Catalogue of Economic Minerals of Canadian, Col. and Ind. Exhib. 1886, p. 51.

[3] These figures are from Phillips' *Gold and Silver*, 1867, p. 320.

87,558*l.* in 1834 and 84,356*l.* in 1858; the smallest 36,772*l.* in 1845 and 26,708*l.* in 1862.

The estimates for *Spain* are very untrustworthy, but it is believed that of late years the annual production of silver has been from 600,000*l.* to 650,000*l.*, a considerable proportion of which is from argentiferous galena.

A singular instance of the discovery of a rich silver lode in a country long explored is that of Hiendelaencina, in Spain. In 1843 a native of the district who had worked in the mines of Mexico noticed the resemblance of a block of stone to the ores with which he was familiar. The result was the discovery and opening up of the richest modern mines in Spain. From 1846 to 1866 they yielded 631,544 lbs. troy of silver, but their production since 1858 has been small.[1]

Reference has already been made (p. 522) to the growing importance of *New South Wales* as a silver-producing country.

The relative amounts of silver produced directly from true silver ores and those obtained by treating ores of other metals is a point of much interest. It was carefully worked out by Professor W. C. Roberts-Austen, in his evidence before the Gold and Silver Commission, 1887 (First Report, p. 325). He gives the following figures for the year 1883, with an estimate of the cost per oz. of silver by each process:—

			Oz.	Cost per oz. s. d.
Treatment of silver ores			49,920,733	1 5
Desilverisation of lead	United States	21,890,000	30,726,000	2 0
	Europe	8,036,000		
	Elsewhere	800,000		
Desilverisation of copper and cupriferous products	Mansfeld	2,382,000	7,200,000	1 11
	Great Britain	328,000		
	Elsewhere	4,490,000		
Refining of native gold			508,000	0 2½
		Total	88,354,733	Mean 1 8

Conclusion.—In taking a general review of the goldfields likely in the near future to yield the most constant supply, it is evident from Table I. that an important place must be given to Russia. With a very slight fall in the produce of Australia and of the United States, Russia would again take her old place at the head of gold-producing countries. With its enormous areas of placer gold only partially worked, and its Siberian veins untouched, a steady yield of gold may be anticipated for many years to come.

The United States and Australasia have of late years been running very closely together, Australia being slightly in excess. In the former there is now a slight tendency to rise in yield.[2] A permanent rise cannot safely be anticipated; a more steady yield than in past years is all that can be hoped for; and this it seems likely may be the case, largely due to quartz-mining. The rapid fall in the gold produce of the United States from 1877 to 1883 was chiefly due to the decrease of silver-mining in the Comstock district, about 40 per cent. of the value here being gold. If we

[1] Phillips and Bauerman, *Metallurgy*, p. 665.

[2] Since this was written the United States statistics for 1886 have appeared. The yield of gold for the last four years is stated as follows:—1883, $30,000,000; 1884, $30,800,000; 1885, $31,801,000; 1886, $35,000,000.

deduct the silver-gold, as is done on Tables I. and II., we see that the fall from 1877 was a very gradual one. The vast placer deposits of California, now in great part sealed by repressive legislation, will be to some extent again worked, either by drift-mining or by hydraulicking with provision for the retention of the débris. Table III. shows a gradual steadying of the produce of Australasia, neither placer nor quartz mining varying much from 1880 to 1885.

Of the newer goldfields the first place should probably be given to Venezuela, &c. The wealth of this country in gold-quartz is well established; but we may perhaps expect for a time a greater development of alluvial mining.

South Africa is generally looked upon with favour as a source from whence our future supply of gold may in part be drawn. Without doubt there are here rich lodes, and it would be strange if this country were destitute of rich placers; though of this there is as yet but little evidence. From these sources mines may possibly be worked at a profit which will give a steady yield of gold; but there is as yet no evidence that the yield will be sufficient in amount to materially influence the world's production.

As regards India the prospect is still less hopeful. That large quantities of gold were raised here by the native princes in times preceding the British rule is tolerably certain; but it is probable that this large production was spread over long periods of time, and certainly it was raised under conditions—of forced labour, &c.—which are not now applicable.

It is unlikely that India will ever contribute to the world's stock sufficient native gold to materially influence the total production. A far more important point is the amount of gold hoarded in India, and the probability or otherwise of that being some day set free. Most estimates concerning gold are ludicrously vague, but on the question of the amount hoarded vagueness is unavoidable. It is known that 130,000,000*l.* of gold has been taken into India since 1835;[1] practically none of this is in circulation (silver being the standard and the coinage of India). How much was hoarded in the centuries preceding 1835 no one can say. If it only equals the amount hoarded since, we have 260,000,000*l.*, or nearly thirteen times the world's present annual production. The original source of this gold and the ways by which it reached India would be an interesting subject for inquiry. Since 1851 it is the gold of the world, mainly sent through England; but in the long past times it was probably in part of native production, in part the gold of Europe, sent over the old trade routes in return for the manufactured articles of India. It is supposed that at least as much silver is hoarded in India as gold. If so the value of silver and gold hoarded in India since 1835 nearly equals in value one-third of the total amount of gold and silver coin now in circulation in the world.

Famines set free some of this gold, and we may perhaps anticipate that the diffusion of Western ideas will free more, but it is unlikely that gold will come from this source in sufficient quantities to influence the annual production of the world.

British Columbia may possibly increase its yield. Other countries

[1] Mr. D. M. Barbour. First Report of the Gold and Silver Commission, 1887, pp. 57–62. See also Dr. Soetbeer's *Materialien*, and Memorandum by Mr. R. H. Inglis Palgrave, in Third Report of Royal Commission on Depression of Trade, 1886.

(as yet little known), as Equatorial Africa, Borneo, and North China, may add somewhat to the world's stock. A steady though comparatively small supply may be looked for from the treatment of silver ores and from the auriferous ores of other metals. In all parts of the world an increased supply is assured by improved methods of mining, milling, and metallurgy; this will be obtained by an actual increase from ore now worked, and also from ores of lower grade, made profitable by the improved methods; whilst tailings, &c., of former times can in some cases be profitably worked over again.

But for all practical purposes the chief sources will probably continue to be the goldfields of the United States, of Australasia, and of Russia, aided by the development of the goldfields of South America. Everything points to a steady production from the three areas first named, and to an increased yield from the last.

As regards the future production of silver it is more difficult to suggest any forecast. It is less a question of where the silver is than of the price at which silver can be sold. The depreciation of silver may be in part due to increased production; but it is due, in at least an equal degree, to changes in the currency of certain nations setting free silver previously absorbed in coinage. If from either cause, or from both combined, the price of silver falls, many mines will cease working; if the price of silver rises, the mines will be reopened and other mines will be developed; and with mines which remain at work ores of low grade may be passed over or stored at low prices, which can be quickly sent into the market if prices rise. So far, therefore, as the natural supply of silver is concerned, the price and the rate of production will react on each other, with a tendency to steady both supply and price.

The natural sources of silver are large and widely spread, and will continue to yield a sufficient supply for many years to come. If the price of silver were to rise, Mexico and South America alone could produce all that the world wants. The yield from the United States will continue. But there is no reason to expect a great increase in the world's production, and, from this cause, a continued fall in price.

Professor Roberts-Austen has shown (see p. 532) that only about 57 per cent. of the world's silver is now produced from true silver ores; the rest is obtained in the metallurgical treatment of other ores in which silver is a more or less important constituent. These ores will continue to be worked for the other metals which they contain, and a steady supply of silver is thus assured. But the price of silver will necessarily exert an important influence upon these works; a slight rise in price will enable many ores to be worked which are now lying untouched, and here again price and supply will act upon and steady each other.

Silver-mining in its various modifications—and the same remark applies to gold obtained from silver ores—may be ranked with metal-mining in its ordinary conditions. Mines which are hopelessly bad will be abandoned; those which are on the verge of paying will be persevered with in hopes of better yield or higher price. In all metal-mining there is far too much gambling and wild speculation, and it is doubtful if, taking metal-mining all round, the value raised equals the expenses. But gold-mining cannot be ranked with ordinary mining. There is a glamour about gold which blinds men to ordinary prudential considerations. The wildest schemes meet with willing supporters, and money is always forth-

coming to develop the poorest mines and to keep them going upon the most shadowy of hopes.

Enormous fortunes have been made in gold-mining by a few lucky speculators. But for one who has been thus fortunate there are scores who have lost heavily.

The facts which we have been considering as to the probable future of gold-mining warrant us in believing that the industry will gradually make for itself a sounder and more honest position. But there must ever be great uncertainty, and therefore a wide field for speculation and for dishonest dealing.

If a steady and undiminished production of gold is essential for the well-being of the world, perhaps what we have most to dread is a sudden influx of common-sense and prudence in the investing public; for this would at once close a great number of mines, and might considerably diminish the world's production. But probably this contingency is sufficiently remote to be safely left out of consideration.

Tables I., II., and III. are, for the years 1852 to 1885, based on the estimates of Sir Hector Hay. These are taken because they give the probable production for each year; Dr. Soetbeer's figures before 1876 give only averages of five years. From 1870 to 1880 Sir Hector Hay's estimates for silver are from 8 to 25 per cent. lower than those of Dr. Soetbeer, chiefly due to differences in Mexico and South America; for gold in the same period they are from 3 to 10 per cent. lower. The differences are greater in the first half of these ten years than in the second half. Before 1870 the differences in the two estimates were comparatively small for silver, but were rather larger for gold. From 1880 the estimates more nearly agree, but Sir Hector Hay's are still rather the lower,

Table IV. (Australasia) is taken from official figures supplied for the 16th Ann. Report of the Deputy Master of the Mint (1886). It differs somewhat from the corresponding diagram in Table I.

The proportions of vein gold to alluvial gold at different periods are taken from a variety of sources. In recent years the estimates are fairly trustworthy, but for former years they are necessarily vague. The proportion of gold in the silver of the United States is taken from the Appendix, by L. A. Garnett, to Bowie's 'Hydraulic Mining.'

The authorities cited throughout this paper have been consulted upon the question generally and not solely for the statements especially referred to. Information has also been obtained from numerous other sources, amongst others from Lock's 'Gold' (1882), the fullest treatise upon that subject, which also contains a lengthy Bibliography; Hague's 'Mining Industries at the Paris Exhibition, 1878'; J. A. Phillips' 'Mining and Metallurgy of Gold and Silver' (1867); Percy's 'Metallurgy of Silver'; the various Catalogues and Guides for the Colonial and Indian Exhibition of last year; Dr. C. Le Neve Foster's 'Report on the Mining Industries of the British Colonies'; Report (in the 'Mining Journal') by R. Etheridge, jun., and T. Davis upon the exhibits; Reports (also in the 'Mining Journal') of Conferences of the Geologists' Association at the Exhibition. Gold was especially referred to in the lectures by Professor V. Ball (India), Dr. Selwyn (Canada), Sir J. von Haast (New Zealand), Mr. F. W. Rudler (Australia). Jervis, 'Dell' Oro in Natura' (1881), gives a table showing, in kilog. and in oz. troy, the produce of various districts from 1848 to 1879. Suess' 'Die Zukunft des Goldes' (1877) contains a Bibliography.

I have also to thank Dr. T. Sterry Hunt and Mr. F. W. Rudler for much assistance and information.

Recent Illustrations of the Theory of Rent, and their Effect on the Value of Land. *By* G. AULDJO JAMIESON.

[A Communication ordered by the General Committee to be printed *in extenso* among the Reports.]

IT is a poor compensation for the agricultural depression under which we labour, that it brings into strong relief some of the rudimentary principles of economic science. It is at neap tide that the secrets of ocean life are revealed to the ordinary observer, and the ebb of our present misfortune enables even casual students to study phenomena which were hid by the flow of our prosperity. Nor will that study be vain if it throws any light on those relations of landlord with tenant—once so close, so cordial, and so sympathetic, which have recently been disturbed—a light which may at least enable those interested to comprehend the reasons of the more recent divergence, and may perhaps help to reconcile interests which may be diverse, but ought never to be antagonistic.

There has been of late a notable revolt on the part of young and foreign economists against the principles which had been generally accepted by the leading authorities as rudimentary in the science of economics. The almost axiomatic dicta on value, wages, profits, and capital which have hitherto been accepted as conclusive, have been challenged, and principles which Mill, Fawcett, and Cairnes held as fundamental have been rudely shaken by heresiarchs, who promise to be hardly less distinguished than the apostles whose creed they assail. But hardly one of the least authority has ventured to controvert the theory of rent propounded by Ricardo. That theory holds the field still in the study and in the lecture-room, but I doubt very much whether it has received that practical exposition which is essential to bring it home to the intelligence of those whom it most immediately concerns. It will be well, therefore, to lay the foundation of any observations on the present condition of rental by stating as clearly as possible and in conventional terms, what, according to recognised definition, rent really is.

Let us assume a farmer in the Lothians, with full appliances and ample skill, to produce a quarter of wheat at a cost for labour, manure, and superintendence of 20*s*. If the same man with the same appliances could raise a quarter of the same wheat on his Argyllshire farm at a cost of not less than 30*s*., it is plain he would lose 10*s*. a quarter if he sold his Argyll wheat at the cost of his Lothian wheat, while he would gain 10*s*. a quarter if he sold his Lothian wheat at the cost of his Argyll wheat. He would, of course, try to sell all his wheat at as much more than 30*s*. as he could get for it; his Lothian wheat and his Argyll wheat would, of course, sell for the same price.

But if the actual price obtainable were only 29*s*. for long enough to establish a definite result, it is plain he would give up growing wheat in Argyll, and would be content to make a profit of 9*s*. per quarter on his Lothian wheat. But that 9*s*. would not be due to any labour, skill, or capital of his; for we assume the same man to be the farmer, and an equality of appliances to be at his disposal, in both cases, and these to be barren in Argyll and fruitful in the Lothians. The 9*s*. is the measure, therefore, of something which the Lothians have which Argyll has not, and it is that something which is expressed by rent.

Of course the same ratiocination may be applied to every species of crop: rent is always the result of comparative fertility.

Rent is, therefore, the practical expression of the excess of fertility of land beyond that productive power which characterises the least fertile land, of which the produce comes into the market, where the comparative value is determined.

And we are now witnessing a practical and interesting illustration and proof of this. There has been a falling off in the quantity of land cultivated in the United Kingdom to the extent of about a million of acres in ten years—about a ninth part of the area in cultivation in 1877. These abandoned acres were certainly not the most fertile, but the least fertile. The cost of producing crops from these acres must therefore have been the highest, because the cost of cultivation of the least fertile land, reckoned on its produce, must always be greatest. The cost of cultivating the least fertile land in cultivation is therefore now much less than it was ten years ago, because there were then in cultivation a million of acres poorer than any acres now cultivated; and therefore the difference between the cost of cultivating the very poorest cultivated land and the very richest is now much less than it was; the horizon of contrast has been narrowed. But rent, we have seen, is just the difference between the cost of cultivating the poorest land that will pay for cultivation and other lands more fertile, and therefore what we call the fall of rent is really the exclusion of poor land from cultivation, and the consequent reduction of the margin between the very poorest land and the several gradations of better land that mark the several degrees of fertility. If we could imagine this process of reduced cultivation to go on until only the richest land, all of uniform fertility, were cultivated, rent would disappear, and we should be face to face with the paradox that land so rich as to defy competition would return nothing to its proprietor. What is the explanation or solution of this paradox? It is this, that according to the theory which has commended itself to all judgment, rent is the measure of *comparative* fertility, and where there is no comparison there can be no measure. Stated otherwise, land must first yield recompense for the labour and capital expended upon it before it can be cultivated, and the theory of rent requires cultivation as the necessary antecedent to rent.

And like all social paradoxes this one vanishes when examined. It assumes all but the richest land to be thrown out of cultivation. That implies a gradual reduction of rent as step by step the poorer land disappears—fades away because it will not pay to cultivate: the richest land survives, because it does pay to cultivate, but it will pay only the cost of cultivation because the competition or other cause which has eaten up the poorer land will eat up that excess beyond cost which, if it could have existed, would have kept the last expiring grade of land in cultivation. Labour, capital, and skill will struggle for their subsistence to the last.

Thus, when closely analysed, we find in the phenomena we examine the usual alternation of cause and effect acting and reacting. Prices fall; the poor land that yields little and costs much to work loses the little margin on which it lived, and goes out of cultivation; the maximum cost of production is thereby reduced, and the worth of the best land is reduced by a corresponding measure. The connection between the fall of price and the fall of rent is not direct and immediate; it is therefore

a fallacy to hold that rent falls just in precise proportion to the fall in the price of produce, so that if land yields four quarters an acre, and wheat falls 1*l.* per quarter, rent must fall 4*l.* per acre. Economic effects are rarely so simple as that, and it is well that we should recognise that such problems require for their solution more than mere arithmetic.

And let us pause for a moment to dissipate another fallacy. Much denunciation is levelled at present at landlords and at rent under the belief that rent contributes to cost, and that when we sweep away rent and landlords we shall have our wheat cheaper by exactly the amount which the landlord now pockets. But no one who really follows up rent to its source can entertain such an idea. In the case I have put, of Argyll yielding wheat at a cost of 30*s.* and the Lothians at a cost of 20*s.*, and the Lothians therefore getting a rent or margin of profit of 10*s.* per quarter while Argyll just lived, what difference would arise if there was no rent in the Lothians? Would the Lothian farmer then sell his wheat for 20*s.* if the farmer, say in Northumberland, was getting 27*s.* 6*d.*? Certainly not; he would get at least 27*s.* 6*d.*, and the consumer would be none the better, and none the wiser, although no landlord existed in the Lothians to claim the tribute due to the extra fertility of that favoured soil. Some foolish farmer may pay more than the extra fertility of the soil he tills justifies, but as a whole the landlords will get just that which measures the various grades of the extra fertility of their land; and if they didn't get it, some one else would, but that some one else would obviously never be the consumer; *he* would pay the same price whoever divided the spoils. The rise or fall of rent is the private affair of landlords and tenants, and is to the community a matter of the purest indifference.

Another fallacy, arising out of that just considered, and which this closer definition of rent enables us to dispose of, is that the ultimate sufferer from agricultural depression is the proprietor. He is not the first, and he is not the last, to suffer: the average rent of the average landowner falls not immediately because prices fall, only indirectly and mediately from that cause. The proximate cause of the fall of his rent is the extinction of cultivation elsewhere, the narrowing of the margin of cultivation; and those who first suffer from that are the labourer and the farmer, the possessors of those functions which exist for cultivation, and operate antecedently to and are the causes of rent. Where there are no leases, rent may fluctuate rapidly and unduly from panic and the accident of seasons, but before the rent of the Lothians or Lincolnshire permanently falls, the labour, capital, and skill employed in cultivating less fertile regions must have perished or migrated.

And, conversely, if by any natural agency the prices of agricultural commodities should rise, or by any artificial method or process should be raised, the proximate result would not be a raising of the rent of the land in general; it would be, *first*, an increased recompense to the labour, skill, and capital employed on the richer lands; *second*, the restoration to cultivation of the next grade of land, inferring increased scope for labour, capital, and skill; and, *third*, a rise of rent, because by that increased area of cultivation the margin had been widened, and the difference between the result of cultivating inferior and superior land had thereby been deepened.

There is therefore no antagonism in this combat with depression between rent, labour, and capital,—there is the closest identity of interest;

and the social cataclysm from the fall of prices, if it comes, will fall ultimately and most severely on the poorer sections of those who depend on the land.

Having now considered what rent is, and shown how the startling statistics of the Agricultural Department corroborate and illustrate the theory of its existence, we may consider another question, too often identified with the preliminary inquiry we have disposed of. Having discovered rent, we have to consider how it can be best paid; the *fact* of rent and the *method* of ascertaining or regulating or paying rent are quite different matters.

There can be no doubt that, just as barter was the earliest form of commerce, rent was originally paid by personal service or in kind; but that does not imply that there was any co-operation or any co-partnership between the landlord and the tenant. The relation of landlord and tenant in respect of rent varied according to the radical idea which underlay that relation. In countries subject to Latin influences the radical idea was certainly that of partnership; the eminently equitable and liberal tendency of Roman practice and jurisprudence favoured that conception of the relation. In Celtic and Saxon communities, and especially in the former, the radical idea, when disentangled from that of service, was sale. In Provence and Italy, a landlord took his share in the production and cultivation of the soil, shared the fertility or sterility of the seasons, shared also the skill or imbecility of the cultivator with whom he was associated. In England, and still more in Scotland and in Ireland, the landlord sold the use of the soil to the cultivator, not for a share in its produce, but for a definite price, payable by instalments while the tenure endured.

This distinction, which has a very important bearing on present phenomena, has been obscured by the circumstance that in ancient times, and indeed until comparatively recently, rent was largely paid in kind, and until still more recent times was often reckoned and measured by the price of the produce. But the payment of rent in kind was due to the incomplete condition of commerce, and to the difficulty of transport and communication. It was difficult, on the one side, for the tenant in any distant part of the country to convert produce into money; on the other side it was very inconvenient for the landlord to procure supplies. Society in these old times was very self-contained, and an old rental, in Scotland at any rate, contained the most elaborate provision for victualling the laird in meal, poultry, beef, mutton, flax, and all commodities,—not, as some imaginative historians have supposed, from any overbearing feudal pride, but from the far more vulgar circumstance that the laird could hardly have lived unless he had been thus provisioned, and the tenant would have had to trudge many a weary mile before he could get the money. We must not, therefore, confuse the method of paying rent in those days with the system of *metayer* cultivation, which at no time prevailed in this country.

The system of regulating the rent by the price of produce, which no doubt had its origin in the necessities or convenience of an earlier age, has in later times been often resorted to, especially where leases prevail, in order to equalise and harmonise the oscillations of value. For many years in a large part of Scotland rents were regulated by the price or value of equal or varying quantities of the three grain crops of that country—wheat, barley, and oats—and the varying proportions in which

these respective grains were used to fix, or rather to measure, the rent, denoted the varying capacity of the farms for the growth of the respective crops. I observe that Lord Tollemache, always an earnest searcher after practical truths and methods, has recently introduced a somewhat similar method of dealing with his rents. But the excessive rates for grain which prevailed during and after the Crimean War induced tenants in Scotland to revolt against a system which forced up rents far above their normal and just amount; and a system which had commended itself for its justice was abandoned on account of the admitted injustice it involved.[1]

Now the pendulum has swung to the other extremity; prices have fallen to an unprecedented extent, and there is now a demand for the readoption of the system of rent in kind, so general thirty or forty years ago. With the glib confidence of crass ignorance, newspaper correspondents with agricultural proclivities urge the arithmetical axiom that produce having fallen 50 per cent., rent must fall in the same proportion, and that the rent, representing the landlord's share of the produce, must fluctuate directly with the value of that produce itself.

This is urged no doubt mainly in the unceasing conflict on Irish land. Within the neutral precincts of this room, and in its calm philosophic atmosphere, one can utter these burning words without the fear of creating a cyclone; but having uttered them, the economist has only to confess that the problem of Irish land is beyond his ken and reach. He deals with a condition of matters in which the ordinary motives of human conduct prevail and have free scope. In this country and in most other countries cultivators work for profit: the ordinary motives and causes of human action produce their ordinary effect, and the task of the economist is to note and to describe these causes and their effects, and to formulate the laws they denote. But in Ireland land in the generic sense is cultivated not for profit but for existence; and that existence is not the mere minimum of subsistence, but an existence brightened by many pleasures, from which, however, those elements of progress, advance, profit, and gain, in our Saxon sense of the terms, are eliminated. The Irish peasant desires to live his Irish life, drawing from the soil the meagre return which suffices not only for his subsistence but for his simple pleasures, practising a penuriousness which is not frugality, and indulging in parsimony as a pastime, combined with a delicious freedom from care which is purchased by the sacrifice of much that the labourer of this country deems indispensable. The chemist would be baffled in a world where the laws of affinity were suspended, and the physicist would be powerless where attraction and gravitation had no force; so economists must retire from seeking to solve problems where the ordinary laws and methods fail to operate.

But let us return to countries where they do operate.

Why was the injustice of the excessive rent, fixed for any length of time by rent in kind, intolerable when prices were excessively high? Why is a rent fixed, also for a long period, by the rent in kind when prices are

[1] The price or value of the produce is one only of several elements in ascertaining the return from a farm. It not infrequently happened that just when prices, and therefore rents, were highest there was a poor crop. Wages, too, rose when prices rose; the rinderpest came when prices were highest, and grain, while it remained in these older leases the sole measure of the rent, became less and less the sole test of the value of the farm.

excessively low equally intolerable? Because, in accordance with the theory of rent, the range of price does not affect rent directly, but only indirectly, through the medium of causes to which price contributes only a proportion of their efficacy.

In comparing the results of recent lettings in various parts of the country, I have been much struck by the circumstance that the fall of rent has been much greater on the larger than on the smaller farms, and that those tenants who themselves labour on the land have evidently suffered less, and are more ready to enter on leases than the larger farmers who have been accustomed only to direct and superintend.[1]

Another fact is the general reluctance of both landlords and tenants to expend capital either on high cultivation or on permanent improvements. Capital is certainly being withdrawn from agriculture.

Applying these facts to the theory of rent, we are led to consider what are and what have been the relations of labour and of capital to rent. Doubtless labour and the recompense of capital are antecedent to and creative of rent; and we all know that under modern circumstances wages are very slow to yield, and that when they do yield they surrender not by reducing the rate, but by restricting the volume. Wages continue high, but the workers become fewer.

Now on large farms the item of wages is a very important one, and if cultivation is to be kept up, it is an inflexible item; but on smaller farms, where wages and superintendence merge, the wage rate is really reduced, the tenant himself insensibly works for less recompense, though the labourer insists on his full rate of wage.

In the same way with capital, the capital of the tenant contributes to the cultivation, and the necessary recompense for its use is also antecedent to rent; but people often forget that the recompense of all capital has of late been largely reduced, whether in the form of interest or of profits, and capital engaged in agriculture cannot be exempt from the influences which affect all capital.

And there is yet another element to be reckoned with. There is a point at which the alternative will be presented to a proprietor whether he will let or even cultivate his land at all, or devote it to pasture instead of tillage. Economically he will let only if sufficient inducement be held out, and there are many persons bent on farming who are prepared to offer such an inducement, although the rent they engage to pay may infringe on what has hitherto been deemed the adequate recompense of the cultivator.

All these considerations combine to arrest the direct influence of the fall of prices on proprietors, and to distribute the loss more equably than is often recognised. The formula prescribed on many platforms is this: The gross produce of a farm was formerly 600*l*., of which cultivation absorbed 200*l*., interest and tenant's profit 200*l*., and rent 200*l*. Prices have fallen 25 per cent.; the return is therefore reduced to 450*l*. Expenses remain the same as before, interest and tenant's profit remain the same; these absorb 400*l*. as before, and the surplus for the landlord is only 50*l*. But let us consider this in the light of commercial experience.

[1] It must not be assumed that this infers a rise of rent of these smaller possessions, or even a fall of rent much less than in other cases. The upkeep of such tenancies is expensive, and it has yet to be seen whether under the altered circumstances of the present times the burden of the upkeep of these small holdings is to fall as exclusively as hitherto on the landlord.

If the farm does not pay, the tenant will reduce the cultivation in extent, or more probably in intensity; he will dispense with a pair of horses, or reduce his labour bill and his manure bill, leaving probably some of his farm in grass. Suppose that is done to the extent of 25 per cent., that saves 50*l.*; and then the tenant cannot expect so large a return on his capital or for his skill, if he reduces his interest from 4 to 3 per cent. and his own recompense in like proportion he will drop 50*l.* The charges antecedent to rent are thus reduced 100*l.*, and the reduction of return being 150*l.*, there remains 50*l.* to be put against the rent. Thus we return to the old formula of the three interests in land, and find these falling together, as they rose together.

But all these considerations, notwithstanding the price or value of the commodities it produces, must ultimately radically affect, though it does not wholly regulate, the rent of the land; and in this period of transition it is most difficult to define what has been, or to anticipate what may be, the final effect of passing experience on the relation of rent to the other elements that constitute property in land. One fact is brought out very prominently at least in Scotland, viz., that the original Celtic and Saxon idea of the leasehold tenure of land has been almost entirely superseded by the more equitable idea of the Latin lease. The idea of the purchase by the tenant for a definite period at a defined price of the productive power of the land had many advantages while prices remained normal and nearly uniform, and the only contingencies were those of the seasons; and it no doubt commended itself to the tenant, while prices tended to rise, and he consequently profited. But when prices do not fluctuate with the seasons, but from other causes oscillate violently and invariably tend downwards, the base of the structure is shaken, and the weaker party to the contract suffers most. In these circumstances it is natural and it is just that the system of long leases should lose its attraction—that the purchase idea and all its consequent feeling of independence and *quasi*-ownership should fade, and that the more natural and equitable idea of co-operation and partnership should rise in appreciation. One of the greatest boons, therefore, which could at present be conferred on landlords and tenants would be the establishment of some system whereby an authoritative return of the value of all sorts of produce in the various districts of the country should be recorded, which would be the measure of rent so far as dependent on price. It is not enough that, as in Scotland, we should have certainly a not very satisfactory, but still a well understood, method of fixing the value of the cereal crops. These contribute less and less to the ascertainment of the real value of the land. We ought to have a similar and a better method of fixing the value of other crops, and of beef, mutton, and dairy produce. With such information, based on a system which should command general confidence, I see nothing to hinder our having rents fixed virtually by the value of the produce of the land, without the complication and difficulty which attaches to the fixing of individual rents of separate farms at frequent intervals, which in the case of the smaller farms would become intolerable. There would be nothing impracticable in the agricultural department having fixed its standard of 20*s.* to the pound on the value of produce, say in 1888, isuing a notice thereafter, year by year, that for each crop and year the pound of rent should be reckoned at 18*s.* or at 22*s.* This would be a system which would soon be understanded of the people, and, without any of the modern leading strings of coercion or

restriction, which some agriculturists so much affect, would, I have no doubt, speedily commend itself to general acceptance, and save landlords and tenants many an argument.[1]

Attempts have been made to obtain such returns which indicate the general feeling in this direction. In a recent report by a committee of the farmers of Banffshire valuable statistics are given of the value of beef for forty years, which, taken along with the ascertained value of oats in that county, present a very fair view of the relative position of agricultural produce year by year.

Year	Oats. Fiars prices	Beef. London prices	Year	Oats. Fiars prices	Beef. London prices
		Per cwt.			Per cwt.
	s. d.	s. d.		s. d.	s. d.
1846	30 6	79 4	1867	24 4	70 0
1847	21 0	65 4	1868	27 10	79 4
1848	16 8	65 4	1869	19 9	86 4
1849	13 6	63 0	1870	23 4	88 4
1850	15 0	53 8	1871	22 7	86 4
1851	16 8	58 4	1872	24 1	93 4
1852	17 8	56 0	1873	25 3	91 0
1853	25 6	67 8	1874	26 7	93 4
1854	26 4	72 4	1875	23 11	91 0
1855	27 2	60 8	1876	21 7	88 8
1856	20 0	70 0	1877	22 7	84 0
1857	19 8	65 4	1878	19 6	79 4
1858	20 6	70 0	1879	21 4	86 4
1859	21 0	74 8	1880	20 6	86 4
1860	23 0	74 8	1881	20 4	86 4
1861	20 6	70 0	1882	20 5	86 8
1862	28 0	70 0	1883	19 11	88 8
1863	16 9	72 4	1884	19 11	86 4
1864	16 0	79 4	1885	19 0	77 0
1865	23 0	74 8	1886	17 0	70 0
1866	24 0	77 0			

I have compiled from the returns of the fiars prices of grain in the counties of Midlothian, Fife, Forfar, Aberdeen, Linlithgow, and Berwick, a statement of the fluctuations of prices of grain grown in these counties.[2]

There are one or two deductions to be drawn from these figures, which are not, I think, readily recognised by those who look at them solely through the spectacles of the agriculturist. They leave no doubt as to the very serious fall in the value of produce. Combining the

[1] See note, p. 540. Might not a thoroughly organised agricultural department afford to landlords and tenants a measure, not only of the value of the produce, but of the fair and proper rent, taking into account in each district not only the value of the produce every year, as contrasted with the value of the standard or initial year, but also the results derivable from fair cultivation in that season: so that those who chose to avail themselves of that method might have year by year such a measure as would give as the rent that fair *share* of the produce of the farm which the parties may have agreed to adopt as the rent,—in a good year with high prices a large rent; in a bad year with low prices a very low rent; in a good year with bad prices, or in a bad year with good prices, a rent measured by those qualified to appreciate and to determine impartially the special influence of each element?

[2] See Appendix.

Banffshire oats and beef, and taking the result of 1850 as the standard, we have these results:—

1846	157	1874	173
1850	100	1880	155
1860	142	1886	126
1870	163		

Taking the fiars of the five counties I have referred to, we have the following results:—

	Wheat	Barley	Oats	Total Cereal	
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	
1860–64	2 1 7¾	1 8 6¾	1 1 8¼	4 11 10¾	100
1865–69	2 10 4¾	1 15 10	1 6 7	5 12 9¾	123
1870–74	2 6 10¾	1 14 3¼	1 5 10½	5 7 0½	116
1875–79	2 0 4¼	1 11 8¾	1 4 6	4 16 7	105
1880–84	1 15 8⅓	1 8 3¾	1 1 9¾	4 5 10	93
1885	1 6 10¾	1 4 5½	1 1 4¼	3 12 8½	79
1886	1 9 3¼	1 1 7½	0 18 5½	3 9 4¼	75

These are startling results viewed alone, but they are far from singular. Take other commodities, and assuming the prices of 1873 as the standard, we have these results:—

	1873		1883	
	£ s. d.		£ s. d.	
Sugar	0 16 10	100	0 12 0	71
Tea	0 0 11½	100	0 5 0	43
Iron	6 7 0	100	2 9 0	38
Copper	4 11 0	100	3 5 0	71
Tin	7 2 0	100	4 13 0	65
Paper	3 9 0	100	1 16 0½	60
Railway carriages	111 10 0	100	85 0 0	76

Agricultural produce has fallen along with other commodities, and the dealers in other commodities must have suffered along with agriculturists. Nor is it difficult to discover in the case of agriculture the proximate cause of this fall. In 1870 there were 88,000,000 acres under wheat in the United States; in 1884, 157,000,000. India in the same period increased from 18,000,000 to 25,000,000. In Europe the acreage in 1870 was 440,000,000 acres; in 1884, 482,000,000; between 1869 and 1879 production of Europe doubled; in 1869–70 the importations into Europe represented 82,000,000*l.*; in 1879 they were 163,400,000*l.* The same liberal supply of other commodities enriched the world, and the world ought to have been rejoicing in bounteous plenty. Why its joy should be turned into sorrow is a question, therefore, which interests commerce not less than agriculture.

But there is another lesson which these statistics of price convey, which many are very slow to learn from them. The system of long leases in Scotland at any rate proceeds, as I have said, on the idea of purchase and sale. A man takes his lease for nineteen years for better or for worse. Suppose him to have done so nineteen years ago—in 1867—he must have fixed the rent with the result of, say, the five previous years before him, to

determine the value of the produce, and having done that, it turns out that towards the close of his lease prices dwindle, and then he comes to the landlord beseeching for a reduction of the rent, *i.e.*, of the last instalments of the price fixed fifteen or sixteen years ago. Now let us see how the Banffshire tenant making this demand really stands. The average value of oats for five years prior to 1867 was 1*l.* 0*s.* 10*d.*; the average price of beef for the same period was 74*s.* 8*d.*; it is reasonable, therefore, to believe that the price of the lease was fixed on these figures. For the first ten years of the lease oats were on the average 1*l.* 3*s.* 9*d.*, or 2*s.* 11*d.* above the anticipated rate, and beef was 88*s.* 2*d.*, or 13*s.* 6*d.* above the calculation: for the next five years of the lease the oats were 1*l.* 0*s.* 5*d.*, and beef was 85*s.*, being 5*d.* below and 10*s.* 4*d.* above the calculated price. Then for the last four years oats averaged 18*s.* 11½*d.* and beef 80*s.* 6*d.* That is to say, for ten years the prices were largely in excess, for five years somewhat in excess, and for four years also still somewhat in excess of the value on which the price was calculated when the bargain was made. In what other trade would any concession be asked or made in such circumstances? Yet almost universally over Scotland concessions have been made to sitting tenants, but I am satisfied justice has never been done in public appreciation to the generosity and good feeling which have characterised the action of the Scotch landlords, who have admitted an interpretation of their bargains which would, in ordinary commercial business, have been scouted as Quixotic. I do not say that this was either an imprudent or an inexpedient course. I think it was most prudent and highly expedient, as tending to keep good tenants, and to inspirit and encourage them, but it none the less deserves recognition in more ample terms than it has received.[1]

So much for rent. Let us for a little see what have been the commercial results of this very serious fall of prices and rent on the saleable value of land itself. For a time, speaking from my own experience, when first the fall of value came to be recognised not as an incidental circumstance but as a permanent economic fact, land was virtually unsaleable; but again economic forces asserted themselves, sellers of land came to recognise the fall, prices of land descended, and the inevitable result has begun to follow; the inexorable laws that regulate supply and demand have begun to operate, and buyers who a few years ago would never have thought of purchasing land, are now buying, and many more begin to

[1] It has now been practically demonstrated that in the contract of letting land there is virtually a warranty implied which is not recognised in law. If the subject of the lease becomes sterile from natural causes, the law does recognise that the claim for rent ceases—the thing let has perished; but if the produce itself becomes sterile, if the price it yields fails to compensate the cost of raising it, though the law recognises no claim on the part of the tenant to consideration, yet in practice the claim is largely conceded, so that virtually a landlord may now be held to guarantee as a condition of rent (1) That the subject rented shall continue to yield normal returns, *i.e.*, shall not from any abnormal cause, such as flooding or destruction, become sterile; and (2) that its produce shall continue to yield a normal return, *i.e.*, shall not be so reduced in price as to afford a return inadequate to defray cost of production and rent. In other and perhaps more scientific words, the landlord has to guarantee that his land shall continue to maintain that position relatively to other cultivated land which, as shown above, shall justify that margin of value beyond that of the least fertile cultivated land, which really constitutes his claim to rent. But this implied guarantee must be applied to the lease as a whole, not to any selected and exceptional portion of it.

think of it. Owing mainly to a financial catastrophe of no ordinary magnitude, I have had within the last few months to bring to sale land in Scotland to an extent of about 39,455 acres, almost wholly arable. The first public sale was on August 24, 1886, and certainly if I had been then told that within a year 33,297 acres would be sold, I should have scouted the prophet. It will not be uninteresting to note the results of these sales in some of their social as well as their economic aspects.

The total acreage we have brought to sale was, as I have said, about 39,455. Of that we are for various reasons reserving 620 acres, and the sale of one property in Fifeshire, extending to 5,479 acres, has also for special reasons been delayed. There remain, therefore, 33,356 acres really to be dealt with here.

The total acreage actually sold has been 33,297; the actual free rental is 27,659*l.*; the valued nett rental was 26,640*l.*; the price realised is 798,940*l.*

Leaving out of view mansion-houses and shootings, and restricting ourselves exclusively to agricultural land and fens, we have sold the land at the average rate of twenty-eight years' purchase of the nett rental: the highest of this class of land was sold at forty years' purchase, the lowest at twenty-two years', but the range has been generally very close on the average.

Then we have sold this large value of land to the following classes of purchasers:—

	Number of Purchasers	Acreage	Price	Free Rental		No. of Years' Purchase	
				Actual	Valued	Actual Rental	Valued Rental
			£	£	£		
I. Member of family under special arrangement	1	5,774	101,200	3,018	2,956	30	$30\frac{3}{4}$
II. Nobleman, owner of adjoining estates	1	2,067	58,000	1,775	1,608	$29\frac{1}{3}$	$32\frac{1}{3}$
III. Adjacent landed proprietors	10	3,209	90,938	2,977	2,958	27	$27\frac{1}{3}$
IV. Mercantile men and others not resident in vicinity	14	11,536	95,762	3,365	3,230	$28\frac{1}{2}$	$29\frac{2}{3}$
V. Manufacturers and others resident in vicinity	34	6,958	324,658	11,788	11,416	27	$27\frac{1}{2}$
VI. Farmers not being tenants on estates	13	1,632	56,967	2,038	1,932	28	$29\frac{1}{2}$
VII. Tenants on the estates .	13	2,121	71,415	2,698	2,540	$26\frac{1}{2}$	28
	86	33,297	798,940	27,659	26,640	28	30

Several of the lots purchased in one name were really acquired for more than one person, and I have no doubt these lands are now held by at least a hundred proprietors.

These figures are illustrative of social facts which, if they develop, as they seem disposed to do, are fraught with much interest and importance; and I am aware that the experience of others corroborates the tendencies they indicate.

1. The prominent feature of these figures is that the demand for land as a form of investment, though materially reduced in intensity, has decidedly grown in extent. Here are the estates of virtually one proprietor distributed at what are certainly fair prices among one hundred new proprietors.

2. From these figures, and from many other facts, I am satisfied that the desire to lay field to field, and to possess a vast extent of land, which has characterised until recently the wealth of modern times, has ceased to operate. This is not due to a mere reduction in value, or to the diminution in the attractions for sport or residence which recent legislation has effected, but to a growing, though perhaps hardly recognised tendency to closer and more personal relations between the occupier and the possessor of land. The craving for extended boundaries—the feeling which the Scotch laird expressed when he desired to 'birze yont'—have given place to a soberer desire to possess more closely a narrower area.

3. Notwithstanding all the recent drawbacks, there can be no doubt that land still continues to possess many attractions. The purchase of land at twenty-eight years' purchase means, after deducting reasonable expenses, not much over 3 or $3\frac{1}{2}$ per cent. on the capital invested. This denotes a high appreciation of the value of the investment.

4. But, on the other hand, the fall in the value of land relatively to other investments is disguised when we compare its present price with that of a few years ago. We have sold a considerable quantity of feu-duties, *i.e.*, permanent ground rents. These used invariably to sell for twenty-two and twenty-three years' purchase, while land fetched thirty or thirty-two years': we have now got twenty-five years' purchase without any difficulty for feu-duties, and often more. This, and the fall of interest on all first-class securities, denote a rise in the value of these investments which ought to have told on land, and would have done so in normal circumstances; but in land there has been a fall and no rise, and in contrasting the present purchase price of land with that of a few years ago, we must not contrast the twenty-eight years' purchase now got with the thirty years' purchase formerly obtained, but with the thirty-three years' purchase we would have got if land had maintained its value relatively to other investments.

5. No small part of the land now being sold is being acquired in parcels much smaller than was usual in former times. The merging in one person of the separate functions of ownership and superintendence, and not unfrequently of labour also, is calculated to bring the cultivator into closer relation with the soil; the dreams of some social revolutionists are to some extent being realised, as such dreams often are, by the silent operation of natural causes, while the dreamers are still rubbing their eyes! And this revolution is being effected under conditions widely different from and much more favourable than those which characterise the impoverished peasantry of some other countries, or could characterise

the subsidised serfs of a landowning community; but just because these small estates are small, an element of value is brought into play which is generally left out of view in larger transactions—the residence, which, on the large estate, is a mere appliance of the farm, and part of its machinery, becomes on these separate estates a distinct and important element of value.

6. In the same direction there is, I think, discernible a growing taste for large and fine residences, with a large domain within the walls, without any or with very little agricultural land beyond; the clashing of feeling and interest engendered of recent years by agitation on the one side and excessive preservation of game on the other has diminished the taste for large estates. I do not think this change of taste, if it develops, is to be welcomed; the exclusiveness of the French *château* or the German *schloss*, with their walled preserves and their *dilettante* sport, and their sharp distinction of caste, will be a poor substitute for the open sporting life of our fathers with its generous freedom of intercourse among all classes, though it may be the natural progeny of the more recent battue. But the social economist can only note what he sees; preferences are seductive.

Lastly.—The great bane of modern landowning has been of late brought into painful relief—debt. We are very fond of putting our forefathers to shame, and blaming settlement and entail for many evils; if the emancipation of land from settlement is to be contemporaneous with its thraldom to debt, it will be out of the frying-pan into the fire. Welcoming, as I do, the enlightened legislation embodied in the Settled Estates Acts passed by Lord Cairns and others, and introduced by Lord Halsbury, and feeling more and more convinced that every proprietor ought to be an unfettered owner, I cannot forget that the motive of entail and settlement was to preserve land from the incubus of debt; and the habit that has within the last century been engendered, not so much among the old aristocracy as among the modern commercial landowners, of holding large tracts of land virtually in trust for a large army of mortgagees, is one of deeper danger to the owners of land and of greater injury to the community than the older system of settlement and entail, and the still more ancient principle of primogeniture which, it appears, we are going to supersede.

What, then, are the practical conclusions to which this cursory survey of the relation of recent experience to theory would lead us?

First.—We are undergoing a process of transition—the old order is passing away—and what the new order is to be is not yet discernible; many of the serious and painful evils from which we suffer are due to that uprooting which must precede replanting.

Second.—One of the most valuable lessons we can deduce from the present condition is to learn the impotence of legislation and of all artificial resources to withstand the power of natural causes. Nothing more markedly illustrates this than the effect of the repeal of the Corn Laws. That step was urged in order to reduce the price of corn, and necessarily rents. It had no meaning if that was not its purpose, and all the afterthought that has striven to disguise the sense of what was said and written in and before 1846, however much it may satisfy sectarian vanity, must be dismissed as unworthy trifling by every honest thinker. Of those who initiated the legislation of 1846 the aim and purpose was the fall of price, and what they thus intended to effect had, as its

necessary consequence, the fall of rent; and the fall of rent must have been occasioned by a diminution of the area of cultivation. But for thirty years after the repeal of the Corn Laws prices rose, rents rose, and the area of cultivation enormously increased; everything happened which the originators of that legislation intended should not happen, and nothing that had been prognosticated by them occurred. Countries which abjured the principles of 1846 flourished not less luxuriantly than countries which adopted them, and those who adopted and abandoned them flourished alike in the days of their faith and in those of their apostasy. Why? Because simultaneously with the repeal of the Corn Laws natural causes began to operate, which swept away all legislative anticipations, as the rising tide obliterates the fortifications of children on the sands. Let us deduce from this the lesson apt to the present crisis. If the repeal of the Corn Laws proved absolutely impotent to reduce rent, what reason have we to believe that their re-enactment would prove more loyal to its design? The growth of enterprise, the spread of communication, the wealth of resource which railroad and steamship awakened; above all, the vivifying flow of gold from regions which were unknown when the seers of 1846 saw visions; baffled, for thirty years, the prognostications of those who promised to labour the spoils of which protection had robbed it. But labour flourished, though land, instead of languishing, grew with redoubled vigour. Is it not a safe deduction, therefore, to draw that labour will languish when land decays? As field by field the area of cultivation narrows, and cottager after cottager departs from the land he has tilled to swell the torrent of labour in the cities,[1] those of us who have faith in the compensation of natural causes may watch with interest when and how the scale will begin to turn, the pendulum begin to swing. Will skill and labour and the land join hands to save themselves from the tide that threatens to engulph them? Or will some fresh impulse come from some unthought-of source to prove that in economics, as in politics, the unexpected always happens?

Third.—What has happened in other trades has occurred in agriculture. Just as the burst of prosperity in 1871–3 stimulated into unhealthy action the iron trade and other kindred trades, so the great burst of agricultural prosperity has unduly stimulated the extension of cultivation, which means the rise of rent. Many acres have been torn out of their native heath and bog, which have speedily yielded the little fertility they had gathered in centuries from the oxygen of the atmosphere and the decay of their own slender herbage, and have now become mere pabulum for converting manure into produce, and will speedily relapse into their native sterility, when the agriculturist discovers that the manure he buys hardly returns more than its own cost.

It is foolish to attribute the loss of rent from such land to any undue

[1] It is a stupid complaint, made by many critics, that those who have recently commented on agricultural depression have no other remedy to suggest than the depopulation of the rural districts of the country. The depopulation is not presented as a remedy for, but as a consequence of, depression. The physician who attempts to diagnose is not to be blamed because he can prescribe no remedy; the economist may point out the nature and cause of depression, and its necessary and natural consequences—it belongs to the practical politician to suggest the remedies; and I have failed to discover any great fertility of suggestion on the part of those who are the sharpest critics and the most ready to sneer at the suggestions of others.

depression; it is the natural effect of natural causes—the subsidence of the tidal wave of an abnormal activity. The country is not really poorer because such land ceases to be prolific: its temporary fertility was deceptive; its owner is poorer only in the sense in which the owner of exhausted minerals is poorer,—he has spent his soil, but he is economically richer, because the undue prosperity has enabled him to derive for a time a bigger return than the land really possessed, and could therefore have yielded under normal conditions.

Fourth.—While it is very dangerous to prognosticate in such times as the present, there is, I think, a convergence of indication that the relation of labour to land is likely to become more intimate and direct, and the singular tendency which society is exhibiting to revert to original types favours the suggestion. If only the richer, or rather richest, land, favourably situated, will yield return for cultivation, it is evident that such land will yield the greatest return to the most diligent cultivator. If the great bulk of our land is, as Sir James Caird anticipates, to become pasture, it is plain that a system of farming requiring little labour, much capital, and great technical skill and superintendence, will gradually become, as of old, the function of the large proprietors; and we shall have a number of small proprietors tilling their own lands near towns, or under conditions favourable to such culture, and the larger proprietors occupying, as they did three centuries ago, large tracts of pasture and owning large herds and flocks, tended by a few skilful wage-earners, whose exertions will probably be stimulated by some participation in the profit. But such revolutions are always slow; and in the complicated economy of modern life, with all its multitudinous influences, the realisation of the most skilful prophecy is apt to be baffled by causes which are beyond the ken even of vaticination: all that the most qualified student can do is to denote the direction in which the causes he can discern, if allowed free scope, necessarily tend. It is needless to point out here the extreme folly of those who contemplate the beneficial occupation of remote or sterile land by small cultivators; the inevitable result of that would be to extend unduly and artificially the area of cultivation—to impoverish the cultivators of those miserable holdings—and to make them the very means of raising the rents of the more fertile land.

Fifth.—The varied purposes and attractions of land give it now, as they have always done, a high value relatively to other investments. It is proved to be susceptible to the same economic and commercial principles as other commodities, and already there are indications that the low value to which it has fallen is producing the usual effect of bringing purchasers into the market who would never have been attracted before. I am convinced that the cause why this tendency has been slow to develop is the fear which prevails of future legislation inequitable to land. This fear is, I think, unfounded; the rowdy politicians of the platform produce a noise which is only the reverberation of their own vociferation. The real tendency of public opinion is decidedly in the opposite direction: the impudent proposals of the early agricultural agitators, which tended to impoverish landlords only that the big tenants might be enriched, have sunk into merited oblivion.[1] The measures now before the public,

[1] *Exempli gratia*: Fixity of tenure, that the *existing* tenants might become copyholders and lairds; Judicial rents, that the *existing* tenants might be inde-

and likely to receive ultimate sanction, tend in quite an opposite direction, and denote that alliance between labour and land, and that direct relation of cultivation with ownership, which I have ventured already to predict; while the gross injustice which has laid the burden of local taxation exclusively on real estate is likely soon to be rescinded when a system of real local government is introduced, and the anomaly of our present taxation is brought into relief by the necessity of either subjecting the community to the local rule of the landed interest, or compelling personalty, if it would participate in local government, to contribute to local taxation. Dismissing the *ignis fatuus* of agricultural apart from industrial protection, the tendency of future legislation in regard to land can hardly fail to be beneficial to the landed interest.

Lastly.—Agriculture is the largest industry in the country, and the most widespread. The depression in iron and coal affects, no doubt, large areas—depression in cotton affects Manchester and Liverpool, in wool Bradford and the Tweed, in sugar Greenock, in silk Coventry; but depression in agriculture is universal, and its effects recur and are brought before us with supreme regularity. In other industries failure is disguised by many devices of hope, and capital contributes many a lift to dwindling profit, so that the manufacturer and the coal-owner require to revert to their ledgers to discern the full effect of depression, and often seek to disguise from themselves, by skilful and hopeful book-keeping, the full effect of their loss. But the farmer has no such solace; as year by year his returns fall short of his outgoings, a far too simple process announces to him the fatal result, and each recurring season of loss intensifies his depression. I doubt whether in reality agriculture be more depressed than other industries, but the victims of the depression are more numerous, the margin of reserve against loss is narrower, the sense of failure is more acute, and the habit of reticence less natural than in other trades. But again I say we may have confidence in the compensation which natural laws generally provide. In 1844 oats were 30*s.* 6*d.* and beef 79*s.* 4*d.* The Corn Laws were then repealed in order to reduce prices, and in 1850 oats had fallen to 15*s.*, and beef to 53*s.* 8*d.* Speedily the rebound came. In 1860 oats were 23*s.*, and beef 74*s.* 8*d.*; in 1870 oats were 23*s.* 4*d.*, and beef 88*s.* 4*d.*; in 1874 oats were 26*s.* 7*d.*, and beef 93*s.* 4*d.*; in 1880 oats were 20*s.* 6*d.*, and beef 86*s.* 4*d.*; in 1886 oats were 17*s.* and beef 70*s.*

In 1850 the complete repeal of the Corn Laws had been effected; and according to all anticipation, and giving effect to every recognisable cause, agricultural prices should have fallen; they did not fall, they rose

pendent of landlords, and exempt from the sordid necessity imposed on other traders, of bargaining for what they desired to acquire; Free sale, that the *existing* tenants might have something to sell that they never paid for, and the selection of the tenant be transferred from the landlords to the existing tenants, along with the right to the latter to exact what the former never claimed, a grassum or fine on entry. The extension of the suffrage has broadened the issues involved, and has consigned these and similar proposals to the bourn whence dishonest political cries do not return. The Land Laws are not now likely to be revolutionised simply in order to create an aristocracy of farmers and to confer a monopoly on existing tenants; but the obvious lesson of these extinct political volcanoes is too valuable to be lost, the community, which has really no interest in the matter (see p. 538), may still be benefited by discerning ere they be forgotten what were the real forces which operated in that upheaval which has now subsided.

enormously. In 1887 no reasons peculiar to agriculture are discernible why prices should fall. The fields of the Far West and the Eastern Cathay, that the iron road has opened up, are no more a threat to agriculture than are the mines of Pennsylvania, or the cotton and jute looms of Massachusetts or the Ganges to other industries. Why should agriculture fail now? It defied prognostication in 1850; why should it not rebound in the future after 1887, when it has no cause specially adverse to defy?

I for one seek the solution of that problem among those elements which affect at present all industries, but mainly in the result of the labours of the Royal Commission appointed to inquire into the recent changes in the relative values of the precious metals.

It is matter of regret that no attempt has been made to discriminate between those causes of agricultural depression which may be regarded as normal and permanent, and those which are accidental, and possibly therefore evanescent.

It was from Russia and the East of Europe that those who dreaded the result of the repeal of the Corn Laws anticipated that the flood of wheat would come to overwhelm British agriculture. At this moment I fancy the British and the Russian agriculturists would both alike gladly compound for such a price as would make the shipping of wheat from Russian ports profitable to either the growers or the importers. It is from America and from India that the flood now comes which sweeps before it the profit of all European agriculture; and it is in the conditions of these countries that we must search for the causes, permanent or evanescent, which now affect our native industry.

As regards America, it is by no means easy to ascertain how far the present enormous supplies and low prices are to be regarded as due to causes normal and permanent, or how far they are due to causes and influences which are likely to be modified or removed. There is a direct conflict of testimony as to whether wheat is or is not the crop most conducive to profit, and most suitable to the climate and other circumstances in many districts from which, at present, very large supplies are drawn. It is said that, in terms of agreements, express or implied, on the large tracts of land sold by the great railway companies wheat is grown where maize and hogs would be more profitable. If maize be the more profitable crop, it will, no doubt, ultimately assert itself and supersede wheat.

The unproductive capital sunk in Western American railroads is also an element which has to be reckoned with. In Canada, whence great supplies are drawn, and greater still are promised, the amount of capital which is dormant is comparatively enormous; besides the large subsidies from the Canadian Government to the Canadian Pacific Railroad, the capital of that concern, 13,000,000*l.*, is not worth above 7,000,000*l.* The capital of three of the largest steam shipping companies trading with America is upwards of 2,875,000*l.*; it is at present absolutely unproductive, and its value in the market is less than 1,000,000*l.* The recent cheapness of American wheat is not, therefore, wholly due to the normal fertility of American land, but largely to the abnormal sacrifices made by the capital which has brought the produce of that land to market. Is that sacrifice permanent? If it be not—if, when the spirit of trade generally revives, the capital sunk in American and Canadian railroads and Atlantic shipping reasserts its claims to fair remuneration,

that remuneration can be gained only by a raising of the cost of transport, which may, to some extent, restore to this country the advantage of its own market.

But in India the one element of the exchange dominates the whole question. If to-day the rupee were worth in London what it is worth in Calcutta, the price of Indian wheat would unquestionably rise to a point which would render its competition with British wheat much less disastrous to the latter than at present it is. Whether bi-metallism or mono-metallism be the more scientific or logical system need not be discussed here, but it does not seem probable that a system of bi-metallism which is neither scientific nor logical, and is certainly not salutary, can permanently be maintained by the British Government in portions of its dominions practically much less remote from each other than Scotland was from England sixty years ago; and, whether the necessary uniformity be established by the remonetisation of silver or by the readoption of the gold standard in India, it seems a safe prophecy to predict that the existing system will soon become intolerable, and either alteration would materially affect the position of British agriculture.

With so many elements to be reckoned with, caution ought to be exercised in accepting as essential what may be only accidental, and in adopting as permanent and definite conditions due to circumstances themselves contingent and temporary.

And my faith in the future of British agriculture, when relieved from those economic evils which afflict it, in common with all other industries, rests on the testimony which the past bears to the fertility of British soil, and to the indomitable skill, energy, and perseverance of the British farmer, and on my belief that this age, so prolific in production, will not always be sterile in profit. Adversity is a harsh teacher, but its lessons are the seed of prosperity. In other times and in other industries the blows that seemed destined to crush have forged and annealed the weapons that ultimately won success. Give back to British agriculture its hope, and the confidence which hope begets, and though the methods of its operation may be different, and the relation of the tillers to the soil they till may be widely altered, I feel confident it will not deny to the more scientific cultivation of the sons the harvest it yielded to the industry and skill of their fathers.[1]

[1] It is assumed that, if the cultivation of the future is to be pastoral, there will be little room for scientific farming: that is a great mistake; there is a wider scope and a more remunerative field for science and skill in the growth of meat than in the growth of grain. The farmers who have made the breeds of British cattle famous throughout the world may find ample scope for their patient skill in determining how best to co-operate with nature in producing the best beef, mutton, and milk at the least possible cost, and that co-operation will be advantageously effected only by those who are familiar with the practical science that is necessary to enable each man for himself to determine what conditions are best in each district for the speedy and profitable creation of the largest amount and best quality of the meat which the district is best suited to raise. If British agriculture is to return to the growth of beef, mutton, and wool, the profit will fall in even larger proportion to the most scientific grazier than the profit of grain-raising does now to the most scientific cultivator.

APPENDIX.—*Statement showing Average Fiars Prices in certain Counties in Scotland from 1860 to 1886.*

GRAIN	COUNTIES							REMARKS
	Aberdeen	Forfar	Fife	Midlothian	Linlithgow	Berwick	Average	
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	
WHEAT, 1860–64	2 1 8¼	2 0 0	2 0 10¼	2 2 11½	2 0 10½	2 3 5¾	2 1 7¾	
" 1865–69	2 8 0½	2 10 0¾	2 9 2¾	2 12 1	2 9 6½	2 13 5	2 10 4¾	
" 1870–74	2 7 8	2 6 5¼	2 5 0¾	2 6 1¼	2 5 11	2 10 2	2 6 10¾	
" 1875–79	1 19 7	1 18 7	1 18 6	1 18 9	2 0 2¼	2 6 7	2 0 4¼	
" 1880–84	—	1 14 6¼	1 14 8½	1 15 4½	1 15 3¼	1 18 8¾	1 15 8½	
" 1885	—	1 5 6	1 7 1¾	1 8 1	1 6 3	1 7 $6\frac{1}{12}$	1 6 10¾	
" 1886	—	1 8 9	1 8 3¼	1 6 6	1 7 8	1 15 2¾	1 9 3¼	
	2 4 9	2 0 10	2 0 7½	2 1 10½	2 1 2¼	2 5 4¼	2 2 5¼	Average 1860 to 1886
BARLEY, 1860–64	1 6 5¼	1 6 8¼	1 8 5	1 10 9½	1 9 8	1 9 4¾	1 8 6¾	
" 1865–69	1 13 0¾	1 13 11½	1 15 10	1 17 10½	1 17 6¼	1 16 8½	1 15 10	
" 1870–74	1 11 4¼	1 12 1¾	1 14 11	1 16 7	1 15 2¾	1 15 5½	1 14 3¼	
" 1875–79	1 9 0	1 9 0¼	1 12 4¾	1 13 8¼	1 12 5½	1 13 8½	1 11 8¾	
" 1880–84	1 7 3	1 5 11½	1 8 9¾	1 9 9¾	1 9 1	1 8 11¼	1 8 3¾	
" 1885	1 3 3	1 3 4	1 5 5⅓	1 5 7	1 4 4	1 4 $10\frac{6}{12}$	1 4 5½	
" 1886	1 1 9	0 19 0	1 0 8¾	1 4 0	1 1 8	1 2 $7\frac{2}{12}$	1 1 7½	
	1 8 11	1 9 0	1 11 5	1 13 1	1 12 0¾	1 12 2¼	1 11 1¼	Average 1860 to 1886
OATS, 1860–64	0 19 4¾	1 0 9¼	1 0 9½	1 3 9	1 1 9½	1 3 7¾	1 1 8¼	
" 1865–69	1 3 11¼	1 6 2¼	1 5 11½	1 8 2½	1 7 1¼	1 8 2½	1 6 7	
" 1870–74	1 3 11¾	1 5 2¾	1 4 10¾	1 7 5¼	1 6 2¼	1 7 7	1 5 10½	
" 1875–79	1 1 9½	1 3 1¾	1 3 6½	1 6 2¼	1 4 10½	1 7 6	1 4 6	
" 1880–84	1 0 2¾	1 0 11¼	1 0 10	1 3 2	1 2 3	1 3 6½	1 1 9¾	
" 1885	0 19 0	1 0 6	1 0 8	1 3 3	1 1 6	1 3 2¼	1 1 4¼	
" 1886	0 17 0	0 17 3	0 17 9¾	0 19 6	0 18 4	1 0 10½	0 18 5½	
	1 1 7	1 2 11	1 2 10¾	1 5 5	1 4 1¼	1 5 9½	1 3 9¼	Average 1860 to 1886

On Certain Laws relating to the Régime of Rivers and Estuaries, and on the Possibility of Experiments on a small scale. By Professor Osborne Reynolds, *F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

1. The object of this communication is to bring before Section G certain results and conclusions with respect to the action of water to arrange loose granular material over which it may be flowing. These results and conclusions were in the first instance arrived at during a long-continued investigation, undertaken with a view to bring the general theory of hydrodynamics into accord with experience, rather than with any special reference to the subject in hand, but have since been to some extent made the subject of special investigation.

2. A systematic study of the *régime* of rivers naturally divides itself under three heads, which may be stated as follows:—

(1.) The more general facts observed as regards the regimen of the beds.

(2.) The movements of sand consistent with these observed facts.

(3.) The necessary actions of the water to produce these movements in the material of the beds.

Observed facts.—Amongst the most general facts to be observed as to the arrangement of the material forming the beds of estuaries are—

(1.) The general stability or steadiness of these beds, so far as is shown by their outline or figure, while, at the same time, as is shown by the obliteration of all footprints and markings casually placed upon them, also by the ripple mark, the material at the surface of these beds is being continually shifted.

(2.) The almost absolute steadiness in figure of some of these beds.

(3.) The gradual changes in the position and form of others—the growth or accumulation of sand-banks in some places, and the wasting of banks or removal of sand in others.

Movement of sand.—As regards the movement of sand consistent with these changes, in the first place the movement, whatever it may be, is one of the surface, and not one in bulk; and in the next place such movement of the surface must be continually going on, whether it produces any change in the figure of the banks or not. The invariable obliteration of footprints and marks which may have been left on the sand at low water, as well as the ripple marks, are absolute evidence of a general disturbance of the surface, and it requires but little observation to show that this disturbance is of the character of a drift of sand, in whatever direction the water may be moving.

Uniform drift.—Where the outline of the banks is not altered, this drift or motion of the sand must be uniform, as much sand being deposited at each point as is removed from that point. Although there may be a general flow of the sand in some direction, if the drift is uniform this movement will not alter the figure of the bed, which, like the balance in another kind of bank, does not depend on the rate of deposit and withdrawal, but on the excess of one of these over the other. The gradual accumulation or diminution of sand at any point is clearly not due to a

simple action of deposit or removal, as they are always attended with the same evidence of the drifting of the surface, and are clearly the result of a difference in the quantities of sand deposited or removed by the drift.

Movement of water.—The manner in which a current of water acts on the granular material forming the bed of the current has been the subject of an investigation by various experimenters. It has been found that the primary action is not so much to drag the grains along the bottom, but to pick them up, hold them in a kind of eddying suspension, at a greater or less height above the bed, for a certain distance and then drop them, so that when the water is drifting the sand there is a layer of water adjacent to the bottom of a greater or less thickness charged to a greater or less extent with sand. The faster the current and the finer the sand the greater will be the thickness of the charged layer, as well as the denser is the charge in the layer.

A certain definite velocity, according to the size and weight of the grains, is required before the water will raise the grains from the bottom, and for all velocities above the minimum necessary to raise the sand the suspended charge increases with the velocity, and the rate of drift or the quantity of sand which passes a particular section increases much faster than the velocity. Attempts have been made with greater or less success to determine exact laws connecting the minimum velocities at which the sand begins to drift with the weight of the grains and other circumstances; also to determine the exact law of the rate of increase of the drift with the velocity.

For my present purpose, however, it is not necessary to enter upon such considerations.

From the facts already mentioned, it will appear that the effect of a uniform current of water over a uniform bed of sand will not be to raise or lower the bed; for, as the charge of sand in the water remains uniform, it must drop as many particles as it raises everywhere on the bed. This is the action of the water in causing a uniform drift.

It is also evident that, if the charge in the water as it comes to any particular place is less than the full charge due to its velocity, it will pick up from that place more sand than it drops, and so increase its charge at the expense of the bed, which will there be scoured or lowered. And conversely, if the water as it arrives at any place is overcharged, it will relieve itself by depositing more than it picks up, and so raise or silt up the bed.

As regards the circumstances which can cause the water to be charged to a greater or less extent than that which it would just maintain with such velocity as it has, the most important are—

(1.) An increasing or diminishing velocity. When the water is moving in a stream from a point where the velocity is less to one where it is greater, the velocity of the actual water as it moves along is increasing, as will also be its normal charge of sand; hence it must be continually picking up more than it deposits. And conversely, when moving from a point of greater velocity to one of less, its normal charge will be continually diminishing through deposits on the bed.

(2.) Another circumstance which affects the charge of sand with which the water may arrive at a particular point is a variation in the character of the bed. If, for instance, water flows from a rocky bed on to sand, it may arrive on the sand without charge, and immediately charges itself at the expense of the bed. Or again, where water flows

from a sandy bottom on to a clean or grassy rocky bottom, it gradually loses its charge silting up the bottom.

The direction in which the sand is moved by the water is sensibly in the direction in which the water which holds the charge is moving. But, as was first pointed out by Dr. James Thomson as affording an explanation of the generally observed fact that the beds of rivers are scoured on their convex sides and silted on their concave, the layers of water adjacent to the bed do not always move in the general direction of the stream. There are often steady cross currents at the bottom, as in the case mentioned, though such cross currents do not exist except under circumstances which may be readily distinguished. The most important of these is that pointed out by Dr. Thomson—curvature in the general direction of the stream, in which case the centrifugal force of the more rapidly moving water above overbalances that of the water retarded by the bottom, and forces the latter back towards the centre of the curve.

This action is universal, where even the lateral boundaries are such as to require the water to move in curved streams; the drift at the bottom does not follow the general direction of the stream, but sets towards the centre of the curve.

The result of the foregoing consideration is to lead to the conclusion that the *régime* of each part of the bed as to maintenance in steady condition, lowering or raising it any time, depends solely on the character of the motion of the water, which if straight and uniform, neither acquiring nor losing velocity, causes a uniform drift in the direction of the stream, which maintains the condition steady. If losing velocity the motion causes a depositing drift and raises the bed; if gaining velocity it causes a scouring drift and lowers the bed; while if curved, the direction of the drift is diverted towards the centre of the curve with its attendant effect to lower the convex side and raise the concave side of the bed. This conclusion seems to be of the utmost importance in dealing with this subject. For if it is correct, not only can the character of the action going on at the bed be inferred from the observed motion of the water, and *vice versâ*, but since, according to this conclusion, the character of the action is independent of the magnitude or velocity of the stream, the results will be the same on a small scale as on a large one, provided only that the character of the motion of the water is the same at all points. In this latter respect this conclusion affords an explanation of a fact that cannot fail to have struck everyone who has observed the sand-beds of the streams running over sands which have been left by the tide, viz., what an almost exact resemblance they bear to each other, whether having the size of a moderate river or of the smallest rivulet.

On the large scale of actual estuaries we can only test the conclusion by actual observation, but on a small scale we can experimentalise in whatever condition of motion we want to test, and readily observe the effects produced; a possibility of which great use has been made in this investigation, and which will be again referred to.

As applied to a *non-tidal* river, in which the direction of the motion is always the same, the foregoing conclusion would lead us to expect that the *régime* would be steady except at the bends, the sources, and the mouth, which is exactly what is observed, so that the conclusion so far agrees with experience. The most striking feature about rivers is the way they wriggle about in the alluvial valleys; a phenomenon pointed to by Lyell as one of those causes still in progress which had produced

the present conditions of the valleys, and which, as already stated, was explained by Dr. Thomson. From the source of the river as the rain-water acquires the velocity, it charges itself with deposit, which charge it maintains with continual taxes and drawbacks until it reaches the ocean or lake, when its water in again losing its velocity deposits its charge, continually carrying forward the bar and extending its delta.

In non-tidal rivers, whether large or small, fast or slow, the characters of these actions are invariable, however much they may differ in intensity. The case of tidal estuaries is, however, by no means so simple. Here we have not, as in a river, a continuous progression of the same character of action at the same point. On the contrary, at every point the action is changed twice a day. For the change in the tidal current does not merely change or reverse the direction of the sand-drift at each part of the bed, but it changes and often reverses the character of this drift, changing what has been a scouring drift during the ebb-tide into a depositing drift during the flood; so that the question as to whether the *régime* is stable, depositing, or scouring is not simply a question as to whether the current at this point is uniform, accelerated, or retarded, but whether the action of the ebb to cause, say, scour is equal to, less than, or greater than the action of the flood to cause deposit.

As there is no likelihood that the resultant effect as regards the general *régime* of two opposing influences will resemble what would have been the simple effect of either of the influences acting alone, this dual control affords abundant reason why the configuration of the beds of these tidal estuaries should differ in character from the configuration of the sand-beds of continuous streams.

There is, however, another and an equally important difference between the general motion of the water in rivers and tidal estuaries.

The function of the estuary is by no means that of a simple channel to conduct the tidal water up and down. It equally discharges the function of a reservoir or basin, to be filled and emptied by each tide.

In consequence of this action as a reservoir the directions of the motions of the water during flood and ebb, and particularly towards the top of the flood and commencement of the ebb, are generally very different from what they would be were the estuary acting the simple part of a channel conducting the water from somewhere to somewhere.

When a vessel is filled by a stream entering on one side the forward motion of the water is stopped before reaching the opposite side. But if, as is always the case, the motion which the water has on entering is more than sufficient to carry it as far as is necessary, the remaining momentum is spent in setting up eddies, or a general circulation in the water, so that when the vessel is full the water within it is not by any means at rest, but may be circulating round or have any other motion. If, then, the water is allowed to flow out the initial motion will not be a steady movement towards the outlet from all parts of the vessel, but those portions of the water which are moving towards the outlet will have their motion accelerated, while those which are moving in the opposite direction will have first to be stopped before they begin to approach the outlet. And thus the ebb will begin earlier at some points in the vessel than at others.

It was the observation of such an effect as this in one of our largest estuaries that first directed my attention to the subject of this paper.

Having investigated this point sufficiently for my own satisfaction

nothing further was done until 1885, when my attention was directed to the inner estuary of the Mersey.

This estuary may be described as a crescent-shaped shallow pan, eleven miles long by three broad, lying north-west and south-east, having its upper horn pointing east and its lower horn north; the northern horn, being prolonged for five miles into a narrow deep channel, runs north to the outer estuary or sandy bay of the sea. One of the most marked features presented by the configuration of the bed of this inner estuary is the invariable preference of the low-tide channels for the concave or Lancashire side; whereas, were the estuary acting merely the part of a river, whether during flood or ebb, it would be expected to follow the usual law, and have the deepest water on the convex or Cheshire side.

That this prevalence of the deepest water on the concave side must be the result of the momentum left in the water by the flood at once seemed to me probable; for if the bottom were level or deepest on the Lancashire side the effect of the curved shape would be to cause the flood entering at the northern horn to follow the south-eastern or Cheshire shore, and the momentum of this water would tend to carry it round the head of the estuary and back along the Lancashire side; would, in fact, tend to set up a circulation before the top of the flood was reached; so that on the Lancashire side the water would be moving down the estuary before the ebb commenced; whence, considering that the flood tends to raise the bottom and the ebb to lower it (for the reasons already pointed out), it seems that the stronger flood on the Cheshire side would raise this side, while the stronger ebb on the Lancashire side would lower this. This is supposing the bottom to be level.

In order to verify these conclusions a vessel was constructed having a flat bottom and a vertical boundary of the same shape as the high-tide line of the inner estuary from the rock to the same distance above Runcorn. The horizontal scale was 2″ to a mile, and the vertical scale 1 inch to 80 feet, $\frac{1}{31800}$.

A shallow tin pan was hinged on to the otherwise open channel at the rock, by raising and lowering which, when full of water, the motion of the tide could be produced throughout the model through the narrows; the true form of the bed of the channel was given to the model by means of paraffin. And in order to obtain approximately the proportional depth in the inner estuary, sand was placed level on the bottom so that the high-tide depth was reduced to the equivalent of about twenty feet. The idea in making this model was not so much to obtain a shifting of the sand as to show the circulation of the water as resulting from the flood tide with a level bottom. In the first instance the tide pan was raised and lowered by hand, but as at the first trial it became evident that the model was not only going to show the expected circulation, but was also capable of showing, by the change in the position of the sand, the effect of this circulation on the configuration of the estuary and other important effects, it was arranged that the model should be worked from a continuously running shaft. The working of the model by hand at once showed that there was only one period of working at which the motion of the water in the model would imitate the motions of the actual tide in the Mersey, which period was found to be about forty seconds; a result that might have been foreseen from the theory of wave motions, since the scale of velocities varies as the square roots of the scales of wave heights, so that the velocities in the model which would correspond to the velo-

cities in the channel would be as the square roots of the vertical scales—about $\frac{1}{33}$—and the ratios of the periods would be the ratio of horizontal scales divided by this ratio of velocities, or

$$\frac{33}{31800}=\frac{1}{950}.$$

Hence, taking 11·25 hours 40,700 seconds as the tidal period, the period of the model

$$=\frac{40700}{950}=42 \text{ seconds (about).}$$

This period was adopted for working the model from the shaft.

It was then found that the circulation at the top of the flood, which was very evident while the bottom was flat, caused a general rise of the sand on the Cheshire side and lowering on the Lancashire, which went on for about 2,000 tides. That during this time, owing to the increase of flood up the Lancashire side and the diminution of that on the Cheshire side which followed from the deepening of the one and the shoaling of the other, the circulation steadily diminished until its character was so changed that it could no longer be called a general circulation, and that after this, although there were further changes in detail going on in the estuary, the two sides maintained a steady condition as regards depth for low tides.

During this time banks were formed and low-tide channels, which resembled in all the principal features those actually in the Mersey; the eastern bank, with the deep sloynes on the Cheshire side, the Devil's Bank and the Garston Channel, the Ellesmere Channel and the deep water in Dungeon Bay and at Dingle Point—all these were very marked in character and closely approximate in scale.

And, what is as important, the causes of these as well as all minor features could be distinctly seen in the model.

The eastern and Devil's Bank are seen during the process of their formation to be simply an internal bar formed by carrying the sand brought down by the ebb out of the narrows and sloyne, until debouching into the broad estuary; its velocity is so far diminished that it can no longer carry its charge, just as happens at the mouth of every river. The peculiar configuration of these banks is explained by the existence of two lines of eddies from about half-tide to the top of the flood: the first of these is caused by the sharp corner at Dingle, and lies between Dingle and Garston, the eddies having their centres over the Devil's Bank; and the second, caused by the divergence of the Cheshire Bank towards Eastham, having the lines of centres over the Eastham Bank. These eddies, which during the most rapid part of the flood only effect a diminution of the velocity of the flood, cause, as the velocity slackens toward the top of the flood, back water to set in along both shores, which back waters, starting the ebb, cause this to be strongest over the Garston and Eastham Channels, which are thus kept open.

The lateral configuration of the shores at Dungeon Bay and at Ellesmere is seen to cause back waters to exist in these bays during the whole of the flood in the latter, and from one to two hours before the top of the flood in the former, which fully accounts for the deep water at these points. The existence of these back waters in the actual channel has been verified. There are many other circumstances brought

to light by this model, which it is impossible for me here to notice without unduly extending the length of this paper, if, indeed, I have not already done so. I will therefore only remark that a second start was made with the sand flat in this second model, and that the result obtained was the same as regards the general features of the estuary. So interesting were these results that it was decided to try a larger scale. A model, having a horizontal scale of 6 inches to a mile, and a vertical scale of 33 feet to an inch, was therefore made, and the tide produced as before. The calculated period of this model is 80 seconds, and experiment bears this out, any variation leading to some tidal phenomena, such as bonos or standing waves, which are not observed in the estuary.

The disadvantage of the larger model is the time occupied—a little more than a minute a tide—which means about 300 tides a day, or 2,000 tides a week. On one occasion the model was kept going for 6,000 tides, and a survey was then made of the state of the sand. And this will be seen to present a remarkable resemblance in the general features to the charts of the Mersey, of which three—1861, 1871, 1881—are shown; in fact the survey from the model presents as great a resemblance to any one of these as they do to each other.

It is impossible for me to enter upon all the points of agreement. Taking into account that in both the estuary and the model there are always changes going on within certain limits, and these changes do affect the currents to a certain extent, it is not to be supposed that there will be exact agreement between the currents at all points and at all states of the tides on the model and estuary. Still there is a general agreement, and in the few verifications I have made I have found that the current found in the model at a particular point and state of tide is also to be found in the estuary.

In one respect the great difference between the model and the estuary calls for remark: this is the much greater depth of the model as compared with its length and breadth. The vertical scale being 33 feet to an inch, and the horizontal scale 880 feet to an inch, so that the vertical heights are nearly twenty-seven times greater than the horizontal distances, such a difference is necessary to get any results at all with such small scale models; and it is only natural to suppose that it would materially affect the action. As a matter of fact, however, it does not seem to do so. And, further, it would seem that, notwithstanding the general resemblance on the *régime* of the beds of large and small streams running over sand, there is in these a similar difference in vertical scale, the smaller streams not only having a greater slope, but also having greater depth as compared with their breadth and steeper banks. So far as the theory of hydrodynamics will apply, it seems that in the model the effects of the momentum of the water would be greater as compared with the bottom resistances than in the estuary, and I think that they are. But the effects of momentum in the estuary greatly preponderate on the resistances, as shown by the fact that the tide at the top of the flood rises some 2 to 3 feet higher at high spring tides than it does at the rock; nor does it do much more than this in the model. In the model it certainly seems that the general *régime* is determined by the momentum effects, and from the almost exact resemblance which this *régime* bears to that of the estuary, it would seem that, although the momentum effects may be diminished by the greater resistance on the bottom, they are still the prevailing influence in determining the configuration of the banks.

Further investigation will doubtless explain this, and also determine the best proportional depths. From my present experience, in constructing another model, I should adopt a somewhat greater exaggeration of the vertical scale. In the meantime I have called attention to these results, because this method of experimenting seems to afford a ready means of investigating and determining beforehand the effects of any proposed estuary or harbour works; a means which, after what I have seen, I should feel it madness to neglect before entering upon any costly undertaking.

I have only to say that, as it was not practicable to exhibit the model to the Section, I have had it working in the new engineering laboratory through the college. Unfortunately it could not be started before Monday, and it will not yet have run more than 1,000 tides, since the sand was put in flat, so that it is not probable that the *régime* is yet quite stable; still the principal features have come out.

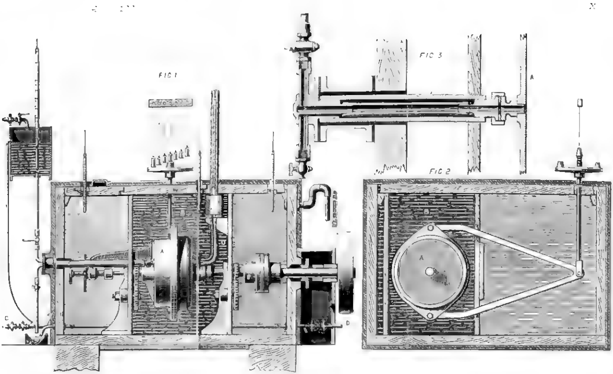
Experiments on the Mechanical Equivalent of Heat on a large scale. By E. A. COWPER *and* W. ANDERSON.

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

[PLATE X.]

THE extremely interesting experiments of Dr. Joule on the mechanical equivalent of heat, led one of the authors of the present paper, some years ago, to speculate on the possibility of conducting such experiments on a much larger scale.

It appeared that it would be possible to employ a powerful machine that would absorb a large amount of power, and to keep it continually going for a whole day at a time, so as to get everything into a thoroughly *normal state*, and so arrange matters as to eliminate all loss or gain from radiation or conduction. The first idea was to employ an india-rubber masticating machine, which would absorb a very large amount of power in a small space, and to enclose it in a small tank, and that again in a larger tank, and then run cold water into the machine, and let the hot water from it run into the small tank, so as to entirely surround the machine with hot water of the same temperature as the water coming out, and then let the water from the first small tank flow into the larger tank, and from that to waste, the outside tank being kept up to the same temperature as the inside tank and the machine, so that the machine should neither lose heat nor absorb it. However, after much consideration, it was thought best to employ one of the late Mr. Froude's dynamometers, such as he used for trying the power of marine engines, though on a smaller scale. Accordingly, through the kindness of Messrs. Heenan and Froude, the loan of such a dynamometer was obtained and fitted up at Erith as above indicated, viz., with a small tank inside a larger one, which last was made of thick wood and well lagged outside with three thicknesses of hair-felt; and this provision was found in practice to be so efficient that the tank of water only lost two degrees in $16\frac{1}{2}$ hours when standing, or about one degree in $8\frac{1}{4}$ hours.



Illustrating Messrs. E. A. Couper and W. Anderson's Paper on Experiments on the Mechanical Equivalent of Heat on a large scale

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Two very large thermometers about a yard long were specially made, having twenty-five inches to fifty degrees, or half an inch to a degree, and these were used throughout for taking the temperature of the cold inflowing water and the hot outflowing water, whilst other thermometers were used throughout the outside tank to enable it to be kept to the same temperature as the outflowing water. The temperature of the outflowing water was of course taken immediately as it flowed out from the Froude's dynamometer, not at the waste. The waste water was carefully taken at short given intervals and weighed (not measured). Several careful observers took observations continually: one took the revolutions of the engine per minute and the total revolutions by a counter that was always going, and registered every revolution throughout the day; another observer took the weight lifted by the dynamometer; another the temperature of the inflowing water; another that of the outflowing water; and another the general temperature of the tank; whilst one in command watched the whole, and saw that everyone kept his register closely.

Before entering on the calculations and results obtained, it will probably be more interesting if the apparatus is first described, and it is to be understood that the object aimed at was to employ continuously a large amount of power (viz., about 5 horse-power) and heat a very considerable quantity of water per minute (viz., about a gallon a minute) to a considerable extent (viz., about 20° Fahr.), whilst all effects of radiation and conduction were neutralised as far as possible. The 'Froude Dynamometer' is shown in elevation and end view, and the lever connected with it, with its rod and scale, for the reception of the weights to be lifted. B is a tank surrounding the 'dynamometer'; C is an outer tank surrounding the inner tank: this is well clothed outside with three thicknesses of hair-felt.

D is a small steam-pipe to keep the outer tank up to the temperature of the inner tank and dynamometer.

The water to be heated is passed into the dynamometer through the india-rubber inlet pipe I, which is itself jacketed with water of the same temperature as the inflowing water; the pipe O is the outlet pipe where the hot water flows out from the dynamometer. The power for driving the dynamometer is communicated through the shaft S, and a piece of wood is introduced between the flanges of the coupling in order to prevent the communication of heat either way, though the temperature of this shaft is kept up by the water in the outer tank.

Thermometers were placed throughout the apparatus to enable it to be kept at an even temperature.

It will at once be seen how completely loss or gain of heat was prevented, as the temperature of the inner tank was the same as the outflowing hot water from the outlet pipe O, and the hot water from it flowed into the outer tank, which had a very small quantity of steam to keep it to the temperature of the hot water from the outlet pipe O.

Thus the outer tank was, so to speak, 'down stream,' and, even if its temperature varied a little, it is impossible to conceive that it could practically affect the temperature of the hot water coming out of the dynamometer, especially as the quantity passing continually was very great, and had thus full command over the temperature of the inner tank.

This it was that enabled the apparatus to be kept in a normal state for many hours together, and from which results might be obtained for

any given length of time. The only thing that interfered at all with the perfect regularity of the experiment, as checked every five minutes, was a very slight variation in the speed of the engine; and an increase of speed of one revolution per minute on 180 revolutions per minute could at once be detected, and was followed after a few minutes by a perceptible rise or fall in the temperature of the outflowing water, as the quantity passing was always almost exactly the same.

The diagrams of the speed of dynamometer, weight lifted, and of the temperature and weight of water heated show what these very slight fluctuations were; and when they were contrasted with the large volume of water heated (viz., about a gallon per minute, twenty degrees) it will be seen how slight they were; and further, as no loss of power on the one hand, or loss of heat on the other, was sustained, it was of minor importance, if indeed of any importance, that the fluctuation should be sometimes slightly above and sometimes slightly below the given point, as the total power was actually registered as well as the total heat produced. The result showed a 'mechanical equivalent of heat' = 769 feet, that is to say, that one pound of water raised 1° Fahr. was equal to one pound lifted 769 feet, and it will be remembered that Professor Joule made it 772 feet.

It is not to be wondered at that the 'equivalent' obtained was slightly lower than that obtained by Professor Joule in his last experiments, as all losses of heat were prevented, and no losses had to be calculated; nor did the specific heat of the apparatus enter into the calculation, as the apparatus was practically kept in a normal state throughout the experiment, and in fact for days together. The authors are aware that the experiments described are by no means complete, and objections may on that account be justly taken to them; but they are anxious to bring the work so far as it has gone before the British Association, in order to benefit by the suggestions and criticisms which discussion would not fail to produce. They intend to resume the experiment at no distant date, and feel sanguine that absolutely trustworthy results will eventually be arrived at.

A small improvement will be made in the machine before prosecuting further experiments, viz., certain precautions to prevent the possibility of any heat being taken up from the surrounding water by any parts of the dynamometer that may be slightly below its general temperature close to the point where the cold water enters.

NOTE.—Since the above paper was read, the authors have heard of the experiment conducted by Professor Marks in 1885 in the United States, with the same object, with the 'Tatham Dynamometer,' belonging to the Franklin Institute, and in which experiment the equivalent of heat was calculated as equal to 772·81 foot-pounds for one degree Fahrenheit. See *Journal of the Franklin Institute*, volume for 1885, p. 453.

On an Electric Current Meter.

By Professor G. FORBES, *M.A., F.R.S. L. & E.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

AT the present moment the mind of electrical engineers is much directed to the successful means of distributing electricity to a large district from central stations by means of that class of induction apparatus which has

received the several names of 'secondary generator,' 'transformer,' and 'converter.' This is the only thoroughly worked out system available to the engineer for an extensive supply of electricity. Currents of an alternating character (*i.e.*, alternately positive and negative in direction, the alternations being at the rate of some hundreds per second of time), and of high tension or pressure, are by this system carried from the engine-house, by comparatively thin and cheap wire conductors, to the points of supply. The only difficulty which has been met is in the designing of a suitable meter. There is absolutely no meter available that pretends to be reliable. The very best indicates a totally different result when the same current is passed through it, if the number of alternations of the current (*i.e.*, the speed of the dynamo) be altered.

It was to overcome this source of trouble and to remove the last difficulty from an otherwise perfect system of electric distribution that the author undertook the labour of designing and perfecting the meter here described. Some idea of the work expended in bringing it to its present state of perfection will be gained when it is stated that the trial observations during the development of the instrument number nearly 10,000.

Seeing that the only electrical actions available were those of chemical action, electro-magnetic action, and heat; that the chemical method is incapable of being used with alternate currents; and that all electro-magnetic meters must vary in their indications with the rapidity of the alternations, the author was led to base his instrument on the heat developed by an electric current. Such an instrument must be equally applicable to continuous currents and to alternate currents, whatever their rate of alternations. Thus a meter is obtained which is practically perfect, and more simple in construction than any of those designed for a more limited range of uses.

The instrument is extremely simple both in principle and in construction. It consists essentially of a flat spiral of iron wire with two terminals. Sometimes these two terminals are united to one wire, the other being attached to the middle of the iron wire. Thus the instrument exhibited may be used as an accurate measure for currents from half an ampère or from one ampère upwards.

Above the conductor a set of vanes is pivoted. This consists of a circular disc of mica with a hole in the centre in which is fixed a paper cone carrying at its apex a pinion with a concentric ruby cup. Round the circumference of the mica disc eight small cylinders of pith are fixed at equal distances, and eight vanes inclined at 45° to the mica disc are attached to the pith cylinders, these vanes being made of the thinnest mica. This set of vanes is supported by the ruby cup resting on a steel point fixed to the base of the instrument. The pinion engages with the first wheel of a train of wheelwork actuating the indexes, which show upon two dials the number of revolutions made by the vanes.

The action of the instrument is very simple. The electric current passing through the iron conductor creates heat, which sets up a convection current in the air, and this causes the vanes to rotate about the vertical axis and drive the clockwork. The number of revolutions indicated on the dials is, through a considerable range of currents, an exact indication of the number of coulombs or ampère-hours which have passed through the conductor. The friction of the ruby cup on the

pivot determines the smallest current which can be accurately measured, and the friction of the clockwork is barely perceptible.

The following table shows the performance of one of these vanes. The conductor used had a resistance of 0·1 ohm; the first line shows the rate at which the current was flowing through the conductor; the second line gives the ratio of current to speed of rotation, a ratio which ought to be constant:—

Current in ampères . . .	·25	·35	·45	·6	·75	1	2	3	6	12
Ratio of current to speed .	76	61·25	50·4	51	50·75	51	51	50·7	51	51·6

When using higher currents the ratio is equally constant.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—Professor Sir R. S. Ball, M.A., LL.D., F.R.S., F.R.A.S., M.R.I.A., Astronomer Royal for Ireland.

THURSDAY, SEPTEMBER 1.

The President delivered the following Address:—

A Dynamical Parable.

Ladies and Gentlemen,—The subject I have chosen for my address to you to-day has been to me a favourite topic of meditation for many years. It is that part of the science of theoretical mechanics which is usually known as the 'Theory of Screws.'

A good deal has been already written on this theory, but I may say with some confidence that the aspect in which I shall invite you now to look at it is a novel one. I propose to give an account of the proceedings of a committee appointed to investigate and experiment upon certain dynamical phenomena. It may appear to you that the experiments I shall describe have not as yet been made, that even the committee itself has not as yet been called together. I have accordingly ventured to call this address 'A Dynamical Parable.'

There was once a rigid body which lay peacefully at rest. A committee of natural philosophers was appointed to make an experimental and rational inquiry into the dynamics of that body. The committee received special instructions. They were to find out why the body remained at rest, notwithstanding that certain forces were in action. They were to apply impulsive forces and observe how the body would begin to move. They were also to investigate the small oscillations. These being settled, they were then to—— But here the chairman interposed; he considered that for the present, at least, there was sufficient work in prospect. He pointed out how the questions already proposed just completed a natural group. 'Let it suffice for us,' he said, 'to experiment upon the dynamics of this body so long as it remains in or near to the position it now occupies. We may leave to some more ambitious committee the task of following the body in all conceivable gyrations through the universe.'

The committee was judiciously chosen. Mr. Anharmonic undertook the geometry. He was found to be of the utmost value in the more delicate parts of the work, though his colleagues thought him rather prosy at times. He was much aided by his two friends, Mr. One-to-One, who had charge of the homographic department, and Mr. Helix, whose labours will be seen to be of much importance. As a most respectable, if rather old-fashioned member, Mr. Cartesian was added to the committee, but his antiquated tactics were quite out-manœuvred by those of Helix and One-to-One. I need only mention two more names. Mr. Commonsense was, of course, present as an *ex-officio* member, and valuable service was even rendered by Mr. Querulous, who objected at first to serve on the committee at all.

He said that the inquiry was all nonsense, because everybody knew as much as they wished to know about the dynamics of a rigid body. The subject was as old as the hills, and had all been settled long ago. He was persuaded, however, to look in occasionally. It will appear that a remarkable result of the labours of the committee was the conversion of Mr. Querulous himself.

The committee assembled in the presence of the rigid body to commence their memorable labours. There was the body at rest, a huge amorphous mass, with no regularity in its shape—no uniformity in its texture. But what chiefly alarmed the committee was the bewildering nature of the constraints by which the movements of the body were hampered. They had been accustomed to nice mechanical problems, in which a smooth body lay on a smooth table, or a wheel rotated on an axle, or a body rotated around a point. In all these cases the constraints were of a simple character, and the possible movements of the body were obvious. But the constraints in the present case were of puzzling complexity. There were cords and links, moving axes, surfaces with which the body lay in contact, and many other geometrical constraints. Experience of ordinary problems in mechanics would be of little avail. In fact, the chairman truly appreciated the situation when he said, that the *constraints were of a perfectly general type.*

In the dismay with which this announcement was received Mr. Commonsense advanced to the body and tried whether it could move at all. Yes, it was obvious that in some ways the body could be moved. Then said Commonsense, 'Ought we not first to study carefully the nature of the freedom which the body possesses? Ought we not to make an inventory of every distinct movement of which the body is capable? Until this has been obtained I do not see how we can make any progress in the dynamical part of our business.'

Mr. Querulous ridiculed this proposal. 'How could you,' he said, 'make any geometrical theory of the mobility of a body without knowing all about the constraints? And yet you are attempting to do so with perfectly general constraints of which you know nothing. It must be all waste of time, for though I have read many books on mechanics, I never saw anything like it.'

Here the gentle voice of Mr. Anharmonic was heard. 'Let us try, let us simply experiment on the mobility of the body, and let us faithfully record what we find.' In justification of this advice Mr. Anharmonic made a remark which was new to most members of the committee; he asserted that, *though the constraints may be of endless variety and complexity, there can be only a very limited variety in the types of possible mobility.*

It was therefore resolved to make a series of experiments with the simple object of seeing how the body could be moved. Mr. Cartesian, having a reputation for such work, was requested to undertake the inquiry and to report to the committee. Cartesian commenced operations in accordance with the well-known traditions of his craft. He erected a cumbrous apparatus which he called his three rectangular axes. He then attempted to push the body parallel to one of these axes, but it would not stir. He tried to move the body parallel to each of the other axes, but was again unsuccessful. He then attached the body to one of the axes and tried to effect a rotation around that axis. Again he failed, for the constraints were of too elaborate a type to accommodate themselves to Mr. Cartesian's crude notions.

We shall subsequently find that the movements of the body are necessarily of an exquisitely simple type, yet such was the clumsiness and the artificial character of Mr. Cartesian's machinery that he failed to perceive the simplicity. To him it appeared that the body could only move in a highly complex manner; he saw that it could accept a composite movement consisting of rotations about two or three of his axes and simultaneous translations also parallel to two or three axes. Cartesian was a very skilful calculator, and by a series of experiments even with his unsympathetic apparatus he obtained some knowledge of the subject, sufficient for purposes in which a vivid comprehension of the whole was not required. The inadequacy of Cartesian's geometry was painfully evident when he reported to the committee on the mobility of the rigid body. 'I find,' he said, 'that the body can neither move parallel to x, nor to y, nor to z; neither can I make

it rotate around x, nor y, nor z; but I could push it an inch parallel to x, provided that at the same time I pushed it a foot parallel to y and a yard backwards parallel to z, and that it was also turned a degree around x, half a degree the other way around y, and twenty-three minutes and nineteen seconds around z.'

'Is that all?' asks the chairman. 'Oh, no,' replied Mr. Cartesian, 'there are other proportions in which the ingredients may be combined so as to produce a possible movement,' and he was proceeding to state them when Mr. Commonsense interposed. 'Stop! stop!' said he, 'I can make nothing of all these figures. This jargon about x, y, and z may suffice for your calculations, but it fails to convey to my mind any clear or concise notion of the movements which the body is free to make.'

Many of the committee sympathised with this view of Commonsense, and they came to the conclusion that there was nothing to be extracted from poor old Cartesian and his axes. They felt that there must be some better method, and their hopes of discovering it were raised when they saw Mr. Helix volunteer his services and advance to the rigid body. Helix brought with him no cumbrous rectangular axes, but commenced to try the mobility of the body in the simplest manner. He found it lying at rest in a position we may call A. Perceiving that it was in some ways mobile, he gave it a slight displacement to a neighbouring position B. Contrast the procedure of Cartesian with the procedure of Helix. Cartesian tried to force the body to move along certain routes which he had arbitrarily chosen, but which the body had not chosen; in fact the body would not take any one of his routes separately, though it would take all of them together in a most embarrassing manner. But Helix had no preconceived scheme as to the nature of the movements to be expected. He simply found the body in a certain position A, and then he coaxed the body to move, not in this particular way or in that particular way, but any way the body liked to any new position B.

Let the constraints be what they may—let the position B lie anywhere in the close neighbourhood of A—Helix found that he could move the body from A to B by an extremely simple operation. With the aid of a skilful mechanic he prepared a screw with a suitable pitch, and adjusted this screw in a definite position. The rigid body was then attached by rigid bonds to a nut on this screw, and it was found that the movement of the body from A to B could be effected by simply turning the nut on the screw. A perfectly definite fact about the mobility of the body has thus been ascertained. It is able to twist to and fro on a certain screw.

Mr. Querulous could not see that there was any simplicity or geometrical clearness in the notion of a screwing movement; in fact he thought it was the reverse of simple. Did not the screwing movement mean a translation parallel to an axis *and* a rotation around that axis? Was it not better to think of the rotation and the translation separately than to jumble together two things so totally distinct into a composite notion?

But Querulous was instantly answered by One-to-One. 'Lamentable, indeed,' said he, 'would be a divorce between the rotation and the translation. Together they form the unit of rigid movement. Nature herself has wedded them, and the fruits of their union are both abundant and beautiful.'

The success of Helix encouraged him to proceed with the experiments, and speedily he found a second screw about which the body could also twist. He was about to continue when he was interrupted by Mr. Anharmonic, who said, 'Tarry a moment, for geometry declares that a body free to twist about two screws is free to twist about a myriad of screws. These form the generators of a graceful ruled surface known as the cylindroid. There may be infinite variety in the conceivable constraints, but there can be no corresponding variety in the character of this surface. Cylindroids differ in size, they have no difference in shape. Let us then make a cylindroid of the right size, and so place it that two of its screws coincide with those you have discovered; then I promise you that the body can be twisted about every screw on the surface. In other words, if a body has two degrees of freedom the cylindroid is the natural and the perfectly general method for giving an exact specification of its mobility.'

A single step remained to complete the examination of the freedom of the body. Mr. Helix continued his experiments and presently detected a third screw, about which the body can also twist in addition to those on the cylindroid. A flood of geometrical light then burst forth and illuminated the whole theory. It appeared that the body was free to twist about ranks upon ranks of screws all beautifully arranged by their pitches on a system of hyperboloids. After a brief conference with Anharmonic and One-to-One, Helix announced that sufficient experiments of this kind had now been made. By the single screw, the cylindroid, and the family of hyperboloids, every conceivable information about the mobility of the rigid body can be adequately conveyed. Let the body have any constraints, howsoever elaborate, yet the definite geometrical conceptions just stated will be sufficient.

With perfect lucidity Mr. Helix expounded the matter to the committee. He exhibited to them an elegant fabric of screws, each with its appropriate pitch, and then he summarised his labours by saying, 'About every one of these screws you can displace the body by twisting, and, what is of no less importance, it will not admit of any movement which is not such a twist.' The committee expressed their satisfaction with this information. It was both clear and complete. Indeed, the chairman remarked with considerable force that *a more thorough method of specifying the freedom of the body was inconceivable.*

The discovery of the mobility of the body completed the first stage of the labours of the committee, and they were ready to commence the serious dynamical work. Force was now to be used, with the view of experimenting on the behaviour of the body under its influence. Elated by their previous success the committee declared that they would not rest satisfied until they had again obtained the most perfect solution of the most general problem.

'But what is force?' said one of the committee. 'Send for Mr. Cartesian,' said the chairman, 'we will give him another trial.' Mr. Cartesian was accordingly requested to devise an engine of the most ferocious description wherewith to attack the rigid body. He was promptly ready with a scheme, the weapons being drawn from his trusty but old-fashioned armoury. He would erect three rectangular axes, he would administer a tremendous blow parallel to each of these axes, and then he would simultaneously apply to the body a forcible couple around each of them; this was the utmost he could do.

'No doubt,' said the chairman, 'what you propose would be highly effective, but, Mr. Cartesian, do you not think that while you still retained the perfect generality of your attack, you might simplify your specification of it? I confess that these three blows all given at once at right angles to each other, and these three couples which you propose to impart at the same time, rather confuse me. There seems a want of unity somehow. In short, Mr. Cartesian, your scheme does not create a distinct geometrical image in my mind. We gladly acknowledge its suitability for numerical calculation, and we remember its famous achievements, but it is utterly inadequate to the aspirations of this committee. We must look elsewhere.'

Again Mr. Helix stepped forward. He reminded the committee of the labours of Mathematician Poinsot, and then he approached the rigid body. Helix commenced by clearing away Cartesian's arbitrary scaffolding of rectangular axes. He showed how an attack of the most perfect generality could be delivered in a form that admitted of concise and elegant description. 'I shall,' he said, 'administer a blow upon the rigid body from some unexpected direction, and at the same instant I shall apply a vigorous couple in a plane perpendicular to the line of the blow.

A happy inspiration here seized upon Mr. Anharmonic. He knew, of course, that the efficiency of a couple is measured by its moment—that is, by the product of a force and a linear magnitude. He proposed, therefore, to weld Poinsot's force and couple into the single conception of a *wrench* on a screw. The force would be directed along the screw while the moment of the couple would equal the product of the force and the pitch of the screw. 'A screw,' he said, 'is to be regarded merely as a directed straight line with an associated linear magnitude

called the pitch. The screw has for us a dual aspect of much significance. No small movement of the body is conceivable which does not consist of a twist about a screw. No set of forces could be applied to the body which were not equivalent to a wrench upon a screw. Everyone remembers the two celebrated rules that forces are compounded like rotations and that couples are compounded like translations. These may now be replaced by the single but far more compendious rule which asserts that wrenches and twists are to be compounded by identical laws. Would you unite geometry with generality in your dynamics? It is by screws, and screws only, that you are enabled to do so.'

These ideas were rather too abstract for Cartesian, who remarked that, as D'Alembert's principle provided for everything in dynamics, screws could not be needed. Mr. Querulous sought to confirm him by saying that he did not see how screws helped the study either of Foucault's Pendulum or of the Precession of the Equinoxes.

Such absurd observations kindled the intellectual wrath of One-to-One, who rose and said, 'In the development of the natural philosopher two epochs may be noted. At the first he becomes aware that problems exist. At the second he discovers their solution. Querulous has not yet reached the first epoch; he cannot even conceive those problems which the "Theory of Screws" proposes to solve. I may, however, inform him that the "Theory of Screws" is not a general dynamical calculus. It is the discussion of a particular class of dynamical problems which do not admit of any other enunciation except that which the theory itself provides. Let us hope that ere our labours have ended Mr. Querulous may obtain some glimmering of the subject.' The chairman happily assuaged matters. 'We must pardon,' he said, 'the vigorous language of our friend Mr. One-to-One. His faith in geometry is boundless—in fact he is said to believe that the only real existence in the universe is anharmonic ratio. It is even his opinion that if a man travelled sufficiently far along a straight line in one direction he would ultimately arrive at the point from which he started.

It was thus obvious that screws were indispensable alike for the application of the forces and for the observation of the movements. Special measuring instruments were devised by which the positions and pitches of the various screws could be carefully ascertained. All being ready the first experiment was commenced.

A screw was chosen quite at random, and a great impulsive wrench was administered thereon. In the infinite majority of cases this would start the body into activity, and it would commence to move in the only manner possible—*i.e.*, it would begin to twist about some screw. It happened, however, that this first experiment was unsuccessful; the impulsive wrench failed to operate, or at all events the body did not stir. 'I told you it would not do,' shouted Querulous, though he instantly subsided when One-to-One glanced at him.

Much may often be learned from an experiment which fails, and the chairman sagaciously accounted for the failure, and in doing so directed the attention of the committee to an important branch of the subject. The mishap was due, he thought, to some reaction of the constraints which had neutralised the effect or the wrench. He believed it would save time in their future investigations if these reactions could be first studied and their number and position ascertained.

To this suggestion Mr. Cartesian demurred. He urged that it would involve an endless task. 'Look,' he said, 'at the complexity of the constraints: how the body rests on these surfaces here; how it is fastened by links to those points there; how there are a thousand-and-one ways in which reactions might originate.' Mr. Commonsense and other members of the committee were not so easily deterred, and they determined to work out the subject thoroughly. At first they did not see their way clearly, and much time was spent in misdirected attempts. At length they were rewarded by a curious and unexpected discovery, which suddenly rendered the obscure reactions perfectly transparent.

A trial was being made upon a body which had only one degree of freedom; was, in fact, only able to twist about a single screw, X. Another screw, Y, was speedily found, such that a wrench thereon failed to disturb the body. It now

occurred to the committee to try the effect of interchanging the relation of these screws. They accordingly arranged that the body should be left only free to twist about Y, while a wrench was applied on X. Again the body did not stir. The importance of this fact immediately arrested the attention of the more intelligent observers, for it established the following general law: If a wrench on X fails to move a body only free to twist about Y, then a wrench on Y must be unable to move a body only free to twist about X. It was determined to speak of two screws when related in this manner as *reciprocal.*

Some members of the committee did not at first realise the significance of this discovery. Their difficulty arose from the restricted character of the experiments by which the law of reciprocal screws had been suggested. They said, 'You have shown us that this law is observed in the case of a body only free to twist about one screw at a time; but how does this teach anything of the general case in which the body is free to twist about whole shoals of screws?' Mr. Commonsense immediately showed that the discovery could be enunciated in a quite unobjectionable form. 'The law of reciprocal screws,' he said, 'does not depend upon the constraints or the limitations of the freedom. It may be expressed in this way:—*Two screws are reciprocal when a small twist about either can do no work against a wrench on the other.*'

This important step at once brought into view the whole geometry of the reactions. Let us suppose that the freedom of the body was such that it could twist about all the screws of a system which we shall call U. Let all the possible reactions form wrenches on the screws of another system, V. It then appeared that every screw upon U is reciprocal to every screw upon V. A body might therefore be free to twist about every screw of V and still remain in equilibrium, notwithstanding the presence of a wrench on every screw of U. A body free to twist about all the screws of V can therefore be only partially free. Hence V must be one of those few types of screw system already discussed. It was accordingly found that the single screw, the cylindroid, and the set of hyperboloids completely described every conceivable reaction from the constraints just as they described every conceivable kind of freedom. The committee derived much encouragement from these discoveries; they felt that they must be following the right path, and that the bounty of Nature had already bestowed on them some earnest of the rewards they were ultimately to receive.

It was with eager anticipation that they now approached the great dynamical question. They were to see what would happen if the impulsive wrench were not neutralised by the reactions of the constraints. The body would then commence to move—that is, to twist about some screw which it would be natural to call the instantaneous screw. To trace the connection between the impulsive screw and the corresponding instantaneous screw was the question of the hour. Before the experiments were commenced, some shrewd member remarked that the issue had not yet been presented with the necessary precision. 'I understand,' he said, 'that when you apply a certain impulsive wrench, the body will receive a definite twist velocity about a definite screw; but the converse problem is ambiguous. Unless the body be quite free, there are myriads of impulsive screws corresponding to but one instantaneous screw.' The chairman perceived the difficulty, and not in vain did he appeal to the geometrical instinct of Mr. One-to-One, who at once explained the philosophy of the matter, dissipated the fog, and disclosed a fresh beauty in the theory.

'It is quite true,' said Mr. One-to-One, 'that there are myriads of impulsive screws, any one of which may be regarded as the correspondent to a given instantaneous screw, but it fortunately happens that among these myriads there is always one screw so specially circumstanced that we may select it as *the* correspondent, and then the ambiguity will have vanished.'

As several members were not endowed with the geometrical insight possessed by One-to-One, they called on him to explain how this special screw was to be identified; accordingly he proceeded:—'We have already ascertained that the constraints permit the body to be twisted about any screw of the system, U. Out of the myriads of impulsive screws, corresponding to a single instantaneous screw,

it always happens that one, but never more than one, lies on U. This is the special screw. No matter where the impulsive wrench may lie throughout all the realms of space, it may always be exchanged for a precisely equivalent wrench lying on U. Without the sacrifice of a particle of generality, we have neatly circumscribed the problem. For one impulsive there is one instantaneous screw, and for one instantaneous screw there is one impulsive screw.'

The experiments were accordingly resumed. An impulsive screw was chosen, and its position and its pitch were both noted. An impulsive wrench was administered, the body commenced to twist, and the instantaneous screw was ascertained by the motion of marked points. The body was brought to rest. A new impulsive screw was then taken. The experiment was again and again repeated. The results were tabulated, so that for each impulsive screw the corresponding instantaneous screw was shown.

Although these investigations were restricted to screws belonging to the system which expressed the freedom of the body, yet the committee became uneasy when they reflected that the screws of that system were still infinite in number, and that consequently they had undertaken a task of infinite extent. Unless some compendious law should be discovered, which connected the impulsive screw with the instantaneous screw, their experiments would indeed be endless. Was it likely that such a law could be found—was it even likely that such a law existed? Mr. Querulous decidedly thought not. He pointed out how the body was of the most hopelessly irregular shape and mass, and how the constraints were notoriously of the most embarrassing description. It was, therefore, he thought, idle to search for any geometrical law connecting the impulsive screw and the instantaneous screw. He moved that the whole inquiry be abandoned. These sentiments seemed to be shared by other members of the committee. Even the resolution of the chairman began to quail before a task of infinite magnitude. A crisis was imminent—when Mr. Anharmonic rose.

'Mr. Chairman,' he said, 'Geometry is ever ready to help even the most humble inquirer into the laws of nature, but Geometry reserves her most gracious gifts for those who interrogate Nature in the noblest and most comprehensive spirit. That spirit has been ours during this research, and accordingly Geometry in this our emergency places her choicest treasures at our disposal. Foremost among these is the powerful theory of homographic systems. By a few bold extensions we create a comprehensive theory of homographic screws. All the impulsive screws form one system, and all the instantaneous screws form another system, and these two systems are homographic. Once you have realised this, you will find your present difficulty cleared away. You will only have to determine a few pairs of impulsive and instantaneous screws by experiment. The number of such pairs need never be more than seven. When these have been found, the homography is completely known. The instantaneous screw corresponding to every impulsive screw will then be completely determined by geometry both pure and beautiful.' To the delight and amazement of the committee, Mr. Anharmonic demonstrated the truth of his theory by the supreme test of fulfilled prediction. When the observations had provided him with a number of pairs of screws, one more than the number of degrees of freedom of the body, he was able to predict with infallible accuracy the instantaneous screw corresponding to any impulsive screw. Chaos had gone. Sweet order had come.

A few days later the chairman summoned a special meeting in order to hear from Mr. Anharmonic an account of a discovery he had just made, which he believed to be of signal importance, and which he was anxious to demonstrate by actual experiment. Accordingly the committee assembled, and the geometer proceeded as follows:—

'You are aware that two homographic ranges on the same ray possess two double points, whereof each coincides with its correspondent; more generally when each point in space, regarded as belonging to one homographic system, has its correspondent belonging to another system, then there are four cases in which a point coincides with its correspondent. These are known as the four double points, and they possess much geometrical interest. Let us now create conceptions of an

analogous character suitably enlarged for our present purpose. We have discovered that the impulsive screws and the corresponding instantaneous screws form two homographic systems. There will be a certain limited number (never more than six) of double screws common to these two systems. As the double points in the homography of point systems are fruitful in geometry, so the double screws in the homography of screw systems are fruitful in Dynamics.'

A question for experimental inquiry could now be distinctly stated. Does a double screw possess the property that an impulsive wrench delivered thereon will make the body commence to move by twisting about the same screw? This was immediately tested. Mr. Anharmonic, guided by the indications of homography, soon pointed out the few double screws. One of these was chosen, a vigorous impulsive wrench was imparted thereon. The observations were conducted as before, the anticipated result was triumphantly verified, for the body commenced to twist about the identical screw on which the wrench was imparted. The other double screws were similarly tried, and with a like result. In each case the instantaneous screw was identical both in pitch and in position with the impulsive screw.

'But surely,' said Mr. Querulous, 'there is nothing wonderful in this. Who is surprised to learn that the body twists about the same screw as that on which the wrench was administered? I am sure I could find many such screws. Indeed, the real wonder is not that the impulsive screw and the instantaneous screw are ever the same, but that they are ever different.'

And Mr. Querulous proceeded to illustrate his views by experiments on the rigid body. He gave the body all sorts of impulses, but in spite of all his endeavours the body invariably commenced to twist about some screw which was *not* the impulsive screw. 'You may try till Doomsday,' said Mr. Anharmonic, 'you will never find any besides the few I have indicated.'

It was thought convenient to assign a name to these remarkable screws, and they were accordingly designated the *principal screws of inertia*. There are for example six principal screws of inertia when the body is perfectly free, and two when the body is free to twist about the screws of a cylindroid. The committee regarded the discovery of the principal screws of inertia as the most remarkable result they had yet obtained.

Mr. Cartesian was very unhappy. The generality of the subject was too great for his comprehension. He had an invincible attachment to the x, y, z, which he regarded as the *ne plus ultra* of dynamics. 'Why will you burden the science,' he sighs, 'with all these additional names? Can you not express what you want without talking about cylindroids, and twists, and wrenches, and impulsive screws, and instantaneous screws, and all the rest of it?' 'No,' said Mr. One-to-One, 'there can be no simpler way of stating the results than that natural method we have followed. You would not object to the language if your ideas of natural phenomena had been sufficiently capacious. We are dealing with questions of perfect generality, and it would involve a sacrifice of generality were we to speak of the movement of a body except as a twist, or of a system of forces except as a wrench.'

'But,' said Mr. Commonsense, 'can you not as a concession to our ignorance tell us something in ordinary language which will give an idea of what you mean when you talk of your "principal screws of inertia"? Pray for once sacrifice this generality you prize so much and put the theory into some extreme shape that ordinary mortals can understand.'

Mr. Anharmonic would not condescend to comply with this request, so the chairman called upon Mr. One-to-One, who somewhat ungraciously consented. 'I feel,' said he, 'the request to be an irritating one. Extreme cases frequently make bad illustrations of a general theory. That zero multiplied by infinity may be anything is surely not a felicitous exhibition of the perfections of the multiplication table. It is with reluctance that I divest the theory of its flowing geometrical habit, and present it only as a stiff conventional guy from which true grace has departed.

'Let us suppose that the rigid body, instead of being constrained as heretofore

in a perfectly general manner, is subjected merely to a special type of constraint. Let it in fact be only free to rotate around a fixed point. The beautiful fabric of screws, which so elegantly expressed the latitude permitted to the body before, has now degenerated into a mere horde of lines all stuck through the point. Those varieties in the pitches of the screws which gave colour and richness to the fabric have also vanished, and the pencil of degenerate screws has a monotonous zero of pitch. Our general conceptions of mobility have thus been horribly mutilated and disfigured before they can be adapted to the old and respectable problem of the rotation of a rigid body about a fixed point. For the dynamics of this problem the wrenches assume an extreme and even monstrous type. Wrenches they still are, as wrenches they ever must be, but they are wrenches on screws of infinite pitch; they have ceased to possess definite screws as homes of their own. We often call them couples.

'Yet so comprehensive is the doctrine of the principal screws of inertia that even to this extreme problem the theory may be applied. The principal screws of inertia reduce in this special case to the three principal axes drawn through the point. In fact we see that the famous property of the principal axes of a rigid body is merely a very special application of the general theory of the principal screws of inertia. Everyone who has a particle of mathematical taste lingers with fondness over the theory of the principal axes. Learn therefore,' says One-to-One in conclusion, 'how great must be the beauty of a doctrine which comprehends the theory of principal axes as the merest outlying detail.'

Another definite stage in the labours of the committee had now been reached, and accordingly the chairman summarised the results. He said that a geometrical solution had been obtained of every conceivable problem as to the effect of impulse on a rigid body. The impulsive screws and the corresponding instantaneous screws formed two homographic systems. Each screw in one system determined its corresponding screw in the other system, just as in two anharmonic ranges each point in one determines its correspondent in the other. The double screws of the two homographic systems are the principal screws of inertia. He remarked in conclusion that the geometrical theory of homography and the present dynamical theory mutually illustrated and interpreted each other.

There was still one more problem which had to be brought into shape by geometry and submitted to the test of experiment.

The body is lying at rest though gravity and many other forces are acting upon it. These forces constitute a wrench which must lie upon a screw of the reciprocal system, inasmuch as it is neutralised by the reaction of the constraints. Let the body be displaced from its initial position by a small twist. The wrench will no longer be neutralised by the reaction of the constraints; accordingly when the body is released it will commence to move. So far as the present investigations are concerned these movements are small oscillations. Attention was therefore directed to these small oscillations. The usual observations were made, and Helix reported them to be of a very perplexing kind. 'Surely,' said the chairman, 'you find the body twisting about some screw, do you not?' 'Undoubtedly,' said Helix; 'the body can only move by twisting about some screw; but, unfortunately, this screw is not fixed, it is indeed moving about in such an embarrassing manner that I can give no intelligible account of the matter.' The chairman appealed to the committee not to leave the interesting subject of small oscillations in such an unsatisfactory state. Success had hitherto guided their efforts. Let them not separate without throwing the light of geometry on this obscure subject.

Mr. Querulous here said he *must* be heard. He protested against any further waste of time; there was nothing for them to do. Everybody knew how to investigate small oscillations; the equations were given in every book on mechanics. You had only to write down these equations, and scribble away till you got out something or other. But the more intelligent members of the committee took the same view as the chairman. They did not question the truth of the formulæ which to Querulous seemed all-sufficient, but they wished to see how geometry could vivify the theory. Fortunately this view prevailed, and new experiments were commenced under the direction of Mr. Anharmonic, who first quelled the elaborate oscillations which

had so puzzled the committee, reduced the body to rest, and then introduced the subject as follows:—

'The body now lies at rest. I displace it a little, and hold it in its new position. The wrench, which is the resultant of all the varied forces acting on the body, is no longer completely neutralised by the reactions of the constraints. Indeed, I can feel it in action. Our apparatus will enable us to measure the intensity of this wrench, and to determine the screw on which it acts.'

A series of experiments was then made, in which the body was displaced by a twist about a screw, which was duly noted, while the corresponding evoked wrench was determined. The pairs of screws so related were carefully tabulated. When we remember the infinite complexity of the forces, of the constraints and of the constitution of the body, it might seem an endless task to determine the connection between the two systems of screws. Here Mr. Anharmonic pointed out how exactly modern geometry was adapted to supply the wants of Dynamics. The two screw systems were homographic, and when a number of pairs, one more than the degrees of freedom of the body, had been found all was determined. This statement was put to the test. Again and again the body was displaced in some new fashion, but again and again did Mr. Anharmonic predict the precise wrench which would be required to maintain the body in its new position.

'But,' said the chairman, 'are not these purely statical results? How do they throw light on those elaborate oscillations which seem at present so inexplicable?'

'This I shall explain,' said Anharmonic; 'but I beg of you to give me your best attention, for I think the theory of small oscillations will be found worthy of it.

'Let us think of any screw a belonging to the system U, which expresses the freedom of the body. If a be an instantaneous screw, there will of course be a corresponding impulsive screw θ also on U. If the body be displaced from a position of equilibrium by a small twist about a, the uncompensated forces will produce a wrench ϕ, which, without loss of generality, may also be supposed to lie on U. According as the screw a moves over U so will the two corresponding screws θ and ϕ also move over U. The system represented by a is homographic with both the systems of θ and of ϕ respectively. But two systems homographic with the same system are homographic with each other. Accordingly, the θ system and the ϕ system are homographic. There will therefore be a certain number of double screws (not more than six) common to the systems θ and ϕ. Each of these double screws will of course have its correspondent in the a system, and we may call them a_1, a_2, &c., their number being equal to the degrees of freedom of the body. These screws are most curiously related to the small oscillations. We shall first demonstrate by experiment the remarkable property they possess.'

The body was first brought to rest in its position of equilibrium. One of the special screws a_1 having been carefully determined both in position and in pitch, the body was displaced by a twist about this screw and was then released. As the forces were uncompensated, the body of course commenced to move, but the oscillations were of unparalleled simplicity. With the regularity of a pendulum the body twisted to and fro on this screw, just as if it were actually constrained to this motion alone. The committee were delighted to witness a vibration so graceful, and, remembering the complex nature of the ordinary oscillations, they appealed to Mr. Anharmonic for an explanation. This he gladly gave, not by means of complex formulæ, but by a line of reasoning that was highly commended by Mr. Commonsense, and such that even Mr. Querulous could understand.

'This pretty movement,' said Mr. Anharmonic, 'is due to the nature of the screw a_1. Had I chosen any screw at random, the oscillations would, as we have seen, be of a very complex type; for the displacement will always evoke an uncompensated wrench, in consequence of which the body will commence to move by twisting about the instantaneous screw corresponding to that wrench; and of course this instantaneous screw will usually be quite different from the screw about which the displacement was made. But you will observe that a_1 has been chosen as a screw in the instantaneous system, corresponding to one of the double screws in the θ and ϕ systems. When the body is twisted about a_1 a wrench is evoked on the double screw, but as a_1 is itself the instantaneous screw, corresponding to

that double screw, the only effect of the wrench will be to make the body twist about a_1. Thus we see that the body will twist to and fro on a_1 for ever; precisely similar statements could have been made about a_2, a_3, &c., corresponding to the other double screws. Finally, we can show that the most elaborate oscillations the body can possibly have may be produced by compounding the simple vibrations on the screws a_1, a_2, &c.'

Great enlightenment was now diffused over the committee, and even Mr. Querulous began to think there must be something in it. Cordial unanimity prevailed among the members, and it was appropriately suggested that the screws of simple vibration should be called *harmonic screws*. This view was adopted by the chairman, who said he thought he had seen a similar expression in 'Thomson and Tait.'

The final meeting showed that real dynamical enthusiasm had been kindled in the committee. Vistas of great mathematical theories were opened out in many directions. One member showed how the theory of screws could be applied not merely to a single rigid body but to any mechanical system whatever. He sketched a geometrical conception of what he was pleased to call a *screw-chain*, by which he said he could so bind even the most elaborate system of rigid bodies that they would be compelled to conform to the theory of screws. Nay, soaring still further into the empyrean, he showed that all the instantaneous motions of every molecule in the universe were only a twist about one screw-chain while all the forces of the universe were but a wrench upon another.

Mr. One-to-One expounded the 'Ausdehnungslehre' and showed that the theory of screws was closely related to parts of Grassman's great work; while Mr. Anharmonic told how Plücker, in his celebrated 'Neue Geometrie des Raumes,' had advanced some distance towards the theory of screws, but still had never touched it.

The climax of mathematical eloquence was attained in the speech of Mr. Querulous, who, with newborn enthusiasm, launched into appalling speculations. He had evidently been reading his 'Cayley' and had become conscious of the poverty of geometrical conception arising from our unfortunate residence in a space of an arbitrary and unsymmetrical description.

'Three dimensions,' he said, 'may perhaps be enough for an intelligent geometer. He may get on fairly well without a four-dimensioned space, but he does most heartily remonstrate against a flat infinity. Think of infinity,' he cries, 'as it should be, perhaps even as it is. Talk not of your scanty straight line as infinity and your miserable pair of circular points. Boldly assert that infinity is an ample quadric, and not the mere ghost of one; and then geometry will become what geometry ought to be. Then will every twist resolve into a right vector and a left vector, as the genius of Clifford proved. Then will the theory of screws shed away some few adhering deformities and fully develop its shapely proportions. Then will——' But here the chairman said he feared the discussion was beginning to enter rather wide ground. For his part he was content with the results of the experiments, even though they had been conducted in the vapid old space of Euclid. He reminded them that their labours were now completed, for they had ascertained everything relating to the rigid body which had been committed to them. He hoped they would agree with him that the inquiry had been an instructive one. They had been engaged in the study of Nature, they had approached the problems in the true philosophical spirit, and the rewards they had obtained proved that

'Nature never did betray
The heart that truly loved her.'

The following Reports and Papers were read:—

1. *Third Report of the Committee for promoting Tidal Observations in Canada.*—See Reports, p. 31.

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2. *Conduction of Electricity through Gases.* *By* Professor A. SCHUSTER, *Ph.D., F.R.S.*

Though a current can usually be sent through a gas only with a high E.M.F., yet, if such a current is passing in any part of a vessel containing a gas, a current can be passed, through any other part with an E.M.F. that is only a fraction of a volt.

This phenomenon doubtless explains certain electrical actions in the atmosphere.

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3. *Instruments for Stellar Photography.* *By* Sir HOWARD GRUBB, *F.R.S.*

Referring firstly to the optical arrangements, the author stated that the condition of extent of field, so important and essential in this work, was one which the optician had never before been asked to consider in telescopic objectives; and he described the direction of a series of experiments which he has been carrying out with the object of obtaining an improvement in this particular. These experiments are not yet complete, but he was able to state that they appeared to point to the conclusion that a very considerably larger field could be obtained than had been at first anticipated.

Speaking then with reference to the mechanical arrangements, he described various modifications and additions which it was desirable to make in the equatorial itself in order that it might best fulfil the conditions required for the new work, and referred specially to the subject of the driving-clock.

The author considers that it is very desirable to have a well-regulated and controlled clock, for although the possession of such does not dispense altogether with the 'eye and hand' work, it does so to a great extent—sufficient at least to relieve the observer of much of the intense strain otherwise required.

By the use of the electric control described at last year's meeting the author has reduced the maximum error to $\frac{1}{10}$th of a second; but this is hardly sufficiently accurate.

The greater part of the residual error exists in the screw itself, which, being necessarily coarse, has not (up to the present) been cut in a micrometer screw-cutting engine, but in an ordinary lathe.

The author is now engaged in constructing two special machines—one for testing and the other for cutting these screws; and he confidently hopes to reduce the errors to $\frac{1}{20}$th of a second by adopting the following precautions:—

1.—Increasing radius of sector.
2.—Cutting screw in special micrometer screw-cutting engine.
3.—Increasing the delicacy of the 'detector' of the control by increasing its scale.
4.—Reducing to the smallest limits the amount of gearing between the clock governor and screw.

The author considers that if the errors be reduced to $\frac{1}{20}$th of a second the accuracy will be sufficient for all practical purposes.

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4. *On the Nature of the Photographic Star-Discs and the Removal of a Difficulty in Measurements for Parallax.* *By* Professor C. PRITCHARD, *D.D., F.R.S.*

The image of a star exposed to a photographic plate driven by a clock having a small rate and subject to small periodic oscillations, as is generally the case with the majority of driving-clocks, is not a simple linear trace, but a series of black dots joined together by intervals less dense.

This will be the generic form of a star-image when these black dots, &c., coalesce, or are superimposed by means of hand-driving.

If, for the purposes of measurement for parallax or otherwise, a bright star be covered over by a stop during the greater part of the duration of the exposure of

the plate, and the stop be then removed for a brief interval, it is shown by experimental measurement that the bright star is accurately represented on the plate.

5. *On the Turbulent Motion of Water between Two Planes.* *By* Professor Sir W. THOMSON, *LL.D., F.R.S.*

6. *On the Theory of Electrical Endosmose and other Allied Phenomena, and on the Existence of a Sliding Coefficient for a Fluid in contact with a Solid.* *By* Professor HORACE LAMB, *M.A., F.R.S.*—See Reports, p. 495.

7. *On the Vortex Theory of the Luminiferous Æther.* *By* Professor Sir W. THOMSON, *LL.D., F.R.S.*—See Reports, p. 486.

8. *On the Ratio of the Two Elasticities of Air.* *By* Professor SILVANUS P. THOMPSON, *D.Sc.*

The method suggested for determining the ratio of the two elasticities was a modification of that of Clément and Desormes. A known additional volume of air was suddenly introduced into a large glass flask by means of a piston in a cylinder, the rise of pressure which resulted being observed in a manometric gauge—first, before the heat had had time to escape; and, secondly, after the initial temperature had been recovered. The author pointed out the utility of this form of apparatus for the teaching of elementary thermodynamics, and showed that this ratio was nothing else than the ratio between the slope of the adiabatic and that of the isothermal drawn through any point of the pressure-volume diagram.

The following is the proof of the proposition.

We have as the adiabatic and the isothermal laws respectively—

$$pv = p_{\prime}v_{\prime} = b \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1),$$

$$p'v^{\gamma} = p_{\prime}v_{\prime}^{\gamma} = a \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

whence

$$\frac{a}{b} = \frac{p_{\prime}v_{\prime}^{\gamma}}{p_{\prime}v_{\prime}} = v^{\gamma-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

Differentiating (1) and (2) with respect to v, and dividing one result by the other, we get—

$$\frac{dp'}{dp} = \frac{a}{b}\gamma v^{-\gamma+1};$$

whence finally

$$\frac{dp'}{dp} = \gamma.$$

9. *A Null Method in Electro-calorimetry.* *By* Professor W. STROUD, *D.Sc., B.A., and* W. W. HALDANE GEE, *B.Sc.*

The method consists in dividing a current between two calorimeters in such a way that the same temperature is maintained in each, as tested either by a thermo-electric or bolometric arrangement. When the calorimetric capacity of the two calorimeters and their contents are adjusted to equality, the corrections for cooling and for the capacity of the calorimeters vanish (see 'Electrical Review,' vol xxi. p. 262; 'Nature,' vol. xxxvi. p. 523). The method is found to be susceptible of great accuracy.

FRIDAY, SEPTEMBER 2.

The following Reports and Papers were read:—

1. *Fourth Report of the Committee for considering the best methods of recording the direct Intensity of Solar Radiation.*—See Reports, p. 32.

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2. *Third Report of the Committee for considering the best means of comparing and reducing Magnetic Observations.*—See Reports, p. 320.

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3. *New Electric Balances.*[1] *By* Professor Sir WILLIAM THOMSON, *F.R.S.*

The balances are founded on the mutual forces discovered by Ampère between the fixed and movable portions of an electric circuit. The mutually influencing portions are usually circular rings. Circular coils or rings are fixed, with their planes horizontal, to the ends of the beam of a balance, and are each acted on by two horizontal fixed rings placed one above and the other below the movable ring. Six grades of instrument are made, named centi-ampère, deci-ampère, ampère, deca-ampère, hecto-ampère, and kilo-ampère balance. The range of each balance is about 25. Thus, the centi-ampère balance will measure currents of from 2 to 50 centi-ampères, while the kilo-ampère balance will measure currents of from 100 to 2,500 ampères. Since the indications of the instrument depend on the mutual forces between two parts of an electric circuit of permanent form and relative position, they are not subject to the changes with time which are so troublesome in instruments the constant of which depends on the strength of permanent magnets.

The most important novelty in these balances is the connection between the movable and the fixed part of the circuit. The beam of the balance is suspended by two flat ligaments made up of fine copper wires placed side by side. These ligaments serve instead of knife-edges for the balance, and at the same time allow the current to pass into and out from the movable coils. The number of wires in each ligament varies from 20 in the centi-ampère to 900 in the kilo-ampère balance. The diameter of the wire is about $\frac{1}{10}$th of a millimètre, and each centimètre breadth of the ligament contains about 100 wires.

The electric forces produced by the current are balanced by means of weights, which can be moved along a graduated scale by means of a self-relieving pendant. Two scales are provided—one a scale of equal divisions, the other a scale the numbers on which are double the square roots of the numbers on the scale of equal divisions. The square-root scale allows the current to be read off directly to a sufficient degree of accuracy for most purposes. When high accuracy is required the fine scale of equal divisions may be used, and the exact value of the current obtained from a table of doubled square roots supplied with the instrument.

An engine-room voltmeter on a similar plan was described. It consists of a coil fixed to the end of a balance-arm, suspended in the manner above described, and acted on by one fixed coil placed below it. The distance of the two coils apart is indicated on a vertical scale by means of a magnifying lever, and serves to indicate the difference of potential between the leads to which the instrument is connected. The coils of the instrument are of copper wire, and an external platinoid resistance of considerably greater amount is joined in circuit with it. The electrical forces are balanced by means of a weight placed in a trough fixed to the front of the movable coil, and weights suited to the temperatures 15°, 20°, 25°, 30° C., as indicated by a thermometer with its bulb in the centre of the coil, are provided.

Two other instruments were described, namely, a marine voltmeter suitable for measuring the potential of an electric-light circuit on board ships at sea, and a magneto-static current-meter suitable for a lamp-counter.

[1] See *Electrician*, May 6, 13, and 20, 1887; also *Telegraphic Review*.

In the marine voltmeter, an oblate spheroid of soft iron is suspended in the centre of, and with its equatorial plane inclined at about 40° to, the axis of a coil of fine copper wire, by means of a stretched platinoid wire. When a current is passed through the coil the oblate of soft iron tends to set its equatorial plane parallel to the axis of the coil, and this tendency is resisted by the rigidity of the suspension-wire.

The lamp-counter is a tangent galvanometer with special provision for preventing damage to its silk fibre suspension, and for allowing the constant to be readily varied by the user to suit the lamps on his circuit.

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4. *Supplement to a Report on Optical Theories.* *By* R. T. Glazebrook, *M.A., F.R.S.*—See Reports, p. 208.

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5. *Description of a Map of the Solar Spectrum.* *By* Professor H. A. Rowland.

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6. *Exhibition of Negatives of Photographs of the Solar Spectrum.* *By* Geo. Higgs.

The author exhibited some negatives obtained by himself with the aid of some temporary instruments, the camera objective being a double convex spectacle-lens of 6 ft. 4 in. focus, and the camera a plain wooden box of the same length. The collimator is only 13 inches long, having a slit exactly 1 mm. in length and about $\frac{1}{200}$th mm. in breadth; the light passes through four prisms of light flint, each having an angle of 45°; the object-glasses are $1\frac{1}{2}$ in. in diameter; the whole being of excellent quality, by Mr. Browning. The detail is such that eighty-one lines may be counted between H^1 and H^2: a strong line, which he had not previously observed, is distinctly observable in the centre of H_2; the nebulous iron line 4045 is resolved into about five nebulous lines. The space between 4101—that is, *h*—and the strong pair on the less refrangible side of it, which is vacant space in Angström's map, contains thirty-five lines, all distinctly visible.

Ilford $\frac{1}{4}$-plates have been used, and in a length of about 10 cm., from G nearly to H_1, between 900 and 1,000 lines may be counted. A great number of bright lines and spaces are observed, which are probably due simply to the absence of lines.

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7. *On the Period of Rotation of the Sun as determined by the Spectroscope.* *By* Henry Crew.

These observations were made with the large spectroscope designed by Professor Rowland for the Johns Hopkins University. With the aid of a good condensing-lens and mirror of plane parallel glass silvered on the front a sharp image of 12·5 mm. diameter was obtained. First one limb and then the other was placed on the slit by rotating the condensing lens about an axis parallel to the axis of the collimator. The displacement of the lines in the spectrum was measured by a micrometer screw in the eyepiece. The grating used was one of Professor Rowland's, having 14,436 lines to the inch, and giving superb definition in the 4th order.

The angle between the solar axis and the slit of the spectroscope was obtained by calculating the parallactic angle; observing, by means of a rotating prism, the angle between the projected image of a plumb-line and the slit; and then adding the sum of these two to the position-angle of the sun, all three being taken with their proper signs.

Twenty-four series of observations, ranging in solar latitude from 23 to 33 degrees, give a final value of $2{\cdot}827 \pm {\cdot}02$ statute miles per second for the relative velocity of the eastern and western limbs of the sun at the equator. The reduction

to the equator is made by Faye's formula, and a correction is introduced for the motion of the earth in its orbit.

This value corresponds to a period of $22\frac{1}{4}$ days, and confirms the observations of Young and Vogel indicating a drift on the solar surface. The writer hopes later to determine the law according to which this drift varies with latitude and find whether it differs from that deduced by Carrington from the motion of sun-spots.

Throughout this work Professor Rowland's aid and suggestions have been invaluable.

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8. *On the Diffraction Bands near the Edge of the Shadow of an Obstacle.* *By* Professor G. F. FITZGERALD, *F.R.S.*

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9. *Recent Determinations of Absolute Wave-lengths.* *By* LOUIS BELL.

The problem, left almost untouched since the completion of Angström's great paper, has been almost simultaneously attacked by four independent experimenters within the past few years, and their publications have thrown some new light on the subject. Angström knew a year or two before his death that the value assigned to his standard of length was certainly too small; but it was left for Thalén to make the necessary correction, which was published about two years ago.

At that time the author was just attacking the subject with the object of confirming or correcting the results obtained by Mr. C. S. Pierce; but long before the work was completed the paper of Müller and Kempf appeared, and during the present summer another research has been added to the list in the admirable thesis of Dr. Kurlbaum.

For convenience the author tabulates the various results, reducing the values given to the corresponding value of the D line for comparison with his own value:—

Thalén (Angström corrected)	5895·86
Pierce	5896·26
Müller and Kempf	5896·25
Bell	5896·08
Kurlbaum	5895·93

Now it is quite evident that these values differ by quantities enormously greater than can be due to pure experimental errors. Aside from these, the errors of a wave-length determination may be due to errors in the assumed values of the standards used, or to errors in the gratings. But, for instance, Müller and Kurlbaum used the same standards, so that there is an outstanding difference of about one part in twenty thousand which must be ascribed to errors in the gratings. In fact there was a discrepancy of more than that amount between the various gratings used by Müller alone. The nature of the error involved was discussed by the author in his paper in the 'Philosophical Magazine' for March last. In the case of Pierce's gratings the error was approximately corrected by calibrating the grating-spaces, and Pierce's result, as given above, was shown to be distinctly too large. The same is certainly true of Müller's result, and for the same reason. The values of Thalén and Kurlbaum are also uncorrected for errors of ruling, and probably would be somewhat increased if the proper corrections were applied.

The standard of length used by the author has shown decided indications of change, and consequently was taken to Berlin this summer and compared with the standard used by Müller and Kurlbaum, from which it appears that the author's value may be too great by as much as one part in a hundred thousand. His gratings will be re-measured at once and the correction for error of ruling recomputed by more than one method, which, it is hoped, will materially increase the accuracy of his result. Meanwhile work will be continued with larger and better gratings.

To sum up. It is now quite certain that the wave-length of D does not differ much from 5896·00, and consequently the numbers usually given for the wave-

lengths of various lines are too small by more than one part in ten thousand—an amount which is inconveniently large. Angström's map contains so few lines, and differs so widely in appearance from the spectrum as seen in a modern spectroscope, that it is quite confusing; and a reference to a line by its place on his map is very insufficient means of identification, besides giving a value for the wave-length which is quite far from the truth.

10. *Twin-Prisms for Polarimeters.* *By* Professor SILVANUS P. THOMPSON, *D.Sc.*

The author described two new forms of twin-prism for use in saccharimeters and polarimeters. The first, intended for use in a manner similar to Laurent's half-shadow prism, consisted of two rectangular polarisers, cut on the plan described by the author at the Association meetings in 1881 and 1886, placed side by side, and having the planes of polarisation in their respective fields inclined at 90° to each other. In the second twin-prism the angle between the planes of the two prisms was about $2\frac{1}{2}°$; and it was intended to be used like the prisms of Jellett or of Cornu. The method of constructing polarisers previously described by the author had special advantages for this purpose, as the polarised field was more homogeneous than that of the Nicol prism, and it was very easy to make the required adjustments of angles.

11. *On the Existence of Reflection when the Relative Refractive Index is Unity.* *By* Lord RAYLEIGH, *LL.D.*, *Sec.R.S.*

The copious undisturbed transmission of light by glass powder when surrounded by liquid of the same index, as in Christiansen's experiment, suggests the question whether the reflection of any particular ray is really annihilated when the relative index is unity for that ray. Such would be the case according to Fresnel's formulæ, but these are known to be in some respects imperfect. Mechanical theory would indicate that when there is dispersion, reflection would cease to be merely a function of the index or ratio of wave-velocities. We may imagine a stretched string vibrating transversely under the influence of tension, and in a subordinate degree of stiffness, to be composed of two parts so related to one another in respect of mass and stiffness that the wave-velocity is the same in both parts for a specified wave-length. But, as it is easy to see, this adjustment will not secure the complete transmission of a train of progressive waves incident upon the junction, even when the wave-length is precisely that for which the velocity is the same.

The experiments that I have tried have been upon plate glass immersed in a mixture of bisulphide of carbon and benzole, of which the first is more refractive and the second less refractive than the glass; and it was found that the reflection of a candle-flame from a carefully cleaned plate remained pretty strong at moderate angles of incidence, in whatever proportions the liquids were mixed.

For a closer examination the plate was roughened behind (to destroy the second reflection), and was mounted in a bottle prism in such a manner that the incidence could be rendered grazing. When the adjustment of indices was for the yellow, the appearances observed were as follows: if the incidence is pretty oblique, the reflection is total for the violet and blue; scanty, but not evanescent, for the yellow; more copious again in the red. As the incidence becomes more and more nearly grazing, the region of total reflection advances from the blue end closer and closer upon the ray of equal index, and ultimately there is a very sharp transition between this region and the band which now looks very dark. On the other side the reflection revives, but more gradually, and becomes very copious in the orange and red. On this side the reflection is not technically total. If the prism is now turned so that the angle of incidence is moderate, it is found that, in spite of the equality of index for the most luminous part of the spectrum, there is a pretty strong reflection of a candle-flame, and apparently without colour. With the aid of sunlight it was proved that in the reflection at moderate incidences there was no marked chromatic selection, and in all probability the blackness of the band in the yellow at grazing incidences is a matter of contrast only.

Indeed, calculation shows that according to Fresnel's formulæ the reflection would be nearly insensible at all parts of the spectrum when the index is adjusted for the yellow. The outstanding reflection is not due to a difference of wave-velocities, but to some other cause not usually taken into account.

Such a cause might be found in the presence of a film upon the surface of the glass, of index differing from that of the interior, and not removable by mere cleaning. The glass plate was accordingly repolished with putty powder, after which the reflection was very decidedly diminished. But neither by this nor by any other treatment (*e.g.* with hydrofluoric acid) has it been found possible to render the reflection of a candle-flame at moderate coincidences even difficult of observation although the adjustment of indices was as good as could be.

It would, however, be hardly safe to conclude that no sufficient film was operative; and I do not see how the question is to be decided unless an experiment can be made upon a surface freshly obtained by fracture.

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12. *On the Magnetisation of Iron in Strong Fields.* *By* Professor J. A. EWING, *B.Sc., F.R.S., and* WILLIAM LOW.

In March of the present year we communicated to the Royal Society ('Proceedings,' vol. xlii. p. 200) the results of experiments on this subject, in which the magnetism of a narrow neck or isthmus of iron placed between the pole-pieces of a large electro-magnet was examined, by suddenly drawing out the piece, or turning it end for end so that the direction of its magnetisation was reversed. The piece examined was in the form of a bobbin with a short central neck turned to a small diameter, and with large spreading conical ends, which were in contact with the pole-pieces and provided an easy path for the lines of induction to converge to the central neck. The metal of the neck was in this way subjected to a much greater magnetic force than it would be practicable to produce by the direct action of a magnetising solenoid. The induction in the iron was measured ballistically by means of a coil of fine wire, in a single layer, round the iron neck. The magnetic force in the air-space closely contiguous to the neck was also measured by means of a second or outer induction coil of a slightly greater diameter than the inner one. This determination of the field allowed a correction to be applied for the air-space enclosed by the inner coil, and it also gave what was probably a close approximation to the value of the magnetic force within the metal itself.

The object of the present note is to describe shortly the results of further experiments of the same kind, the details of which may be reserved for subsequent publication.

In the former experiments an electro-magnet with pole-pieces $5\frac{1}{4}$ cms. square was used. The conical ends of the bobbins tested brought the central neck down to a diameter of 0·65 cm. in one form of sample and 0·923 cm. in another form. With this we succeeded in forcing the induction $\mathfrak{B}$ in Lowmoor and Swedish wrought iron up to values lying between 32,000 and 33,000 c.g.s. units, the strength of the magnetic field in the air close to the neck being then about 11,000 c.g.s. units.

Large as those values were, they have been greatly exceeded in the present series of experiments. In the former paper we pointed out that the magnetic induction of the iron examined showed no sign of approaching a maximum, and that the value to which it might be forced by the 'isthmus' method depended on the scale of the experiments. Through the kindness of Professor Tait in allowing the large electro-magnet of the Edinburgh University Laboratory to be brought to Dundee, we have now been able to subject iron to much higher magnetising forces, and to secure a much greater concentration of the lines of induction. The Edinburgh magnet is one of exceptional power. Its limbs, which are vertical, are about 60 cms. long, and the cores are 10·7 cms. in diameter. Rectangular blocks of soft wrought iron 9·6 cms. square serve for pole-pieces. To allow the old bobbins to be effectively used we added a pair of conical intermediate pieces of soft

iron, which virtually formed an extension of the conical ends of the bobbin. Between these the bobbin was placed, the form generally used being that described in the previous paper as sample A. The neck of this sample had originally a diameter of 0·923 cm., and consequently a section of 0·669 square cm., or about $\frac{1}{140}$ that of the pole-pieces. As in the former experiments, the highest values of magnetism have been reached with Lowmoor iron, and nearly as high values with Swedish iron.

The same Lowmoor bobbin that had been formerly used (sample A) had its magnetism measured by withdrawing it from the field, while the magnet with all its numerous coils in series was excited by a current which ranged up to 40 ampères. At the highest value the induction $\mathfrak{B}$ in the neck was 38,000 c.g.s., and the outside field, close to the neck, was 18,900 c.g.s. A Swedish sample of the same shape gave an induction of 37,620 with a field of about the same force.

To push the induction to still higher values the Lowmoor sample was then turned down in the central neck until the diameter was reduced to 0·397 cm. This made its section only $\frac{1}{740}$ of the section of the pole-pieces. Careful determinations, several times repeated, then gave for the highest induction the enormous value 43,500 c.g.s., the outside field being 25,620 c.g.s. Here, as in the other figures already given, the induction stated is that which is found after the air-space enclosed by the inner coil is allowed for, and after a suitable allowance is made for the residual magnetism of the piece. The residual induction is only about 500 c.g.s. units.

The ratio $\dfrac{\mathfrak{B}}{\text{outside field}}$ in this extreme case is 1·7, and the quantity $\dfrac{\mathfrak{B} - \text{outside field}}{4\pi}$, which would be the intensity of magnetism $\mathfrak{I}$ if the magnetic force within the metal were identical in value with the outside field, is 1420. In the former experiments this quantity had values which decreased from 1680 to 1620, while the induction increased from about 25,000 to 32,000; here, with an induction of 43,500, it has fallen off to a much more marked extent. We cannot yet speak with any certainty as to the degree of approximation of this quantity to the intensity of magnetism $\mathfrak{I}$; unless, however, the mean magnetic force within the neck is much less than the force at the surface, the results show that $\mathfrak{I}$ is becoming less as the induction is being forced to these extreme values—in other words, that the iron is tending towards diamagnetism in the manner Weber's theory leads us to expect. The question is one of the greatest interest, and we are now endeavouring to obtain a better knowledge of the magnetic force within the metal by examining the variation of the force at short distances from the surface of the neck.

A final effort was made to force the induction in Lowmoor iron to higher values, by turning the central neck down still further, until its section was less than $\frac{1}{1500}$ of the section of the pole-pieces, and annealing the bobbin carefully before magnetising it. The value of $\mathfrak{B}$ then reached was 45,350 c.g.s. units, which is the greatest induction recorded in any of our experiments.

With cast iron the induction has been forced to 31,270 c.g.s. by applying a magnetic force of 16,900.

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13. *On the Magnetisation of Hadfield's Manganese Steel in Strong Fields. By* Professor J. A. Ewing, *B.Sc., F.R.S., and* William Low.

Messrs. Hadfield of Sheffield manufacture a steel containing about 12 per cent. of manganese and 0·8 per cent. of carbon which possesses many remarkable qualities. Prominent amongst these, as the experiments of Hopkinson, Bottomley, and Barrett have shown, is a singular absence of magnetic susceptibility. Hopkinson, by applying a magnetic force $\mathfrak{H}$ of 244 c.g.s. units to a specimen of this metal, produced a magnetic induction $\mathfrak{B}$ of only 310 c.g.s. units: in other words, the permeability μ was 1·27, and the intensity of magnetisation $\mathfrak{I}$ was a little over five units. We are indebted to him for the suggestion that it would be interesting to apply to this metal the 'isthmus' method of magnetisation (the results of which, as applied

to wrought iron and cast iron, have been described in a former paper), with the view of seeing whether the magnetic resistance of manganese steel could be broken down by applying a very strong magnetising force.

Messrs. Hadfield were kind enough to supply a sample of the metal for experiment, out of which a bobbin was turned, with some difficulty, of a form resembling those used in testing wrought iron and cast iron, but with a wider central neck. The bobbin was magnetised by placing it between the pole-pieces of Professor Tait's large magnet; and the induction within the neck, and also the field in the air immediately surrounding the neck, were measured in the usual way, by the help of two induction coils and by drawing the bobbin suddenly out from between the magnet-poles. A large number of readings were taken, while the field magnet was excited with currents ranging from about 1 to 40 ampères. These gave values of the magnetic field (in the air immediately surrounding the central neck of the steel bobbin) ranging up to 5,200 c.g.s. units, and values of the induction $\mathfrak{B}$ within the neck ranging up to 7,700 c.g.s. units. To be more exact, these latter were the values of that part of the induction which disappeared when the metal was drawn out of the field, but the correction for residual magnetism was probably negligible. The ratio of induction to field had a nearly constant value when the field ranged from about 1,000 c.g.s. to 5,200 c.g.s.; the values of this ratio calculated from the observations fluctuate somewhat, but do not appear to undergo any progressive change. The mean value of $\frac{\mathfrak{B}}{\text{outside field}}$ is 1·45, a quantity which we may probably take without substantial error as the value of the permeability μ.

To test the influence of still stronger magnetic fields a second series of experiments was made with a composite bobbin made up of a cylindrical shank—extending from end to end—of manganese steel, and conical pole-pieces of soft wrought iron forced on to the steel shank so as to leave only a short length of it (about three millimeters) bare in the middle. With a given current in the field magnets this gave much higher values of the field and the induction in the central neck, because the wrought iron cones now substituted for the conical ends of the solid steel bobbin that had been formerly used gave an easier path for the lines of induction to converge to the central neck. The field now ranged up to values slightly exceeding 10,000 c.g.s. units, and the highest induction reached was about 15,000 c.g.s. units. In this series of experiments, as in the former series, the ratio of induction to field fluctuated irregularly; but its mean value was nearly identical with the former mean—namely, 1·46. The intensity of magnetisation $\mathfrak{I}$ was forced up to values lying between 300 and 400 c.g.s.

The experiments make it clear that, even under magnetic forces extending to 10,000 c.g.s. units, the resistance which this manganese steel offers to being magnetised suffers no breakdown in any way comparable to that which occurs in wrought iron, cast iron, or ordinary steel at a very early stage in the process of magnetisation. On the contrary, the permeability is approximately constant under large and small forces. This conclusion has some practical interest. It has been suggested that this steel should be used for the bed-plates of dynamos, and in other situations where a metal is wanted that will not divert the lines of induction from neighbouring spaces. In such cases the magnetic forces to which manganese steel would be subjected would certainly lie below the limit to which the force has been raised in these experiments. We may therefore conclude that in these uses of the material it may be counted upon to exhibit a magnetic permeability only fractionally greater than that of copper, or brass, or air.

SATURDAY, SEPTEMBER 3.

The following Reports and Papers were read:—

1. *Second Report of the Committee on Electrolysis.*—See Reports, p. 336.

2. *On some points in Electrolysis and Electro-convection.* *By* Professor G. WIEDEMANN.—See Reports, p. 347.

3. *On Ohm's Law in Electrolytes.* *By* G. F. FITZGERALD, *F.R.S.*, *and* FRED. TROUTON.—See Reports, p. 345.

4. *Further Researches concerning the Electrolysis of Water.* *By* Professor VON HELMHOLTZ.

5. *Experiments on the possible Electrolytic Decomposition of Alloys.* *By* Professor W. C. ROBERTS-AUSTEN, *F.R.S.*—See Reports, p. 341.

6. *Experiments on the Speeds of Ions.* *By* Professor O. J. LODGE, *F.R.S.*

7. *On Chemical Action in a Magnetic Field.* *By* Professor H. A. ROWLAND.

8. *On the Action of an Electric Current in hastening the Formation of Lagging Compounds.* *By* Dr. J. H. GLADSTONE, *F.R.S.*—See Reports, p. 344.

9. *Experiments on Electrolysis and Electrolytic Polarisation.* *By* W. W. HALDANE GEE, *B.Sc.*, HENRY HOLDEN, *B.Sc.*, *and* CHARLES H. LEES, *B.Sc.*

This is a preliminary notice of experiments that are in progress in the Owens College Physical Laboratory. The experiments fall under four heads: (A) electrolysis under pressure; (B) time-rate of fall of polarisation in closed circuit; (C) irreciprocal conduction; (D) production of a dense oily-looking liquid in electrolysis with palladium electrodes.

(A) Numerous experiments have been made in order to determine the variation of resistance and polarisation of a sealed voltameter in which dilute sulphuric acid is electrolysed between platinum wire electrodes, it being thus subjected to the pressure of the evolved gases. It was found that the resistance markedly decreased, and the polarisation also decreased to a slight extent. These changes may, however, it is thought, be due to change of temperature, the influence of which would appear, from later experiments, not to have been fully eliminated.

In two cases no change whatever was perceived—firstly, when two platinum *plates* were used as electrodes; and, secondly, when two voltameters were connected together, forming a sealed vessel, one voltameter being used to increase the pressure, while observations were made on the other voltameter.

As it has not been possible to obtain glass tubes sufficiently strong for the high pressures desired, an apparatus of gun-metal has been constructed. This apparatus, which is fitted with a Bourdon's gauge recording to six tons on the square inch, may also be arranged for pressure experiments in general by attaching to it, by means of a strong metal tube, a suitable receiver.

In two of the experiments where the pressure had reached between 200 and 300 atmospheres, the evolved oxygen and hydrogen gases combined with explosion, although precautions had been taken to prevent the gases from coming into contact with the platinum, except in the liquid.

(B)[1] The object of this research was to try to learn the parts played by the various portions of the evolved gases—(1) that occluded by the electrodes; (2) that deposited on them; (3) that contained in the liquid, in influencing the time-rate of depolarisation. The method employed was to vary the conditions under control—*e.g.*, time of charging, density of current, &c.—and to observe the time-rate of the fall of the polarisation thus produced in closed circuit. It was found to be very difficult to apply this method; because, though the conditions under control were kept as constant as possible, yet the time-rates of fall in two successive observations were often different. This was thought to be due to the insufficient cleaning of the electrodes between each experiment, and various methods were tried to remedy it, with the general result that the more perfect the cleaning became the more regular did the curves giving the time-rate of the fall of the polarisation become, but still the inconsistencies were not wholly removed. Heating of the electrodes by the electrical current seemed to be preferable to the other methods of heating.

(C) Whilst electrolysing strong sulphuric acid between platinum electrodes it was noticed that when the current density at the *anode* had exceeded a certain value decomposition apparently ceased. The value of the anode current density necessary to produce this phenomenon is increased by diminishing the concentration or increasing the temperature of the acid, and is diminished by cleaning the electrodes. It was found that the great diminution of the current was not caused by the formation of an opposing E.M.F., but by a sudden increase of from 500 to 50,000 ohms in the resistance of the voltameter. That the insulating condition occurs at the anode is shown by successively replacing the kathode and the anode by a clean plate; in the first case, the stoppage of the current persists; in the second case, the current is readily conducted. The cause *may* be a sheath of oxygen bubbles, which firmly adhere to the anode when the insulating condition is formed. The film is removed by breaking the current momentarily, or short-circuiting the voltameter, or reversing the current.

(D) During the electrolysis of various liquids with palladium electrodes it has been observed that a dense-looking liquid streams from *one* of the electrodes (the *anode* in dilute sulphuric acid, the *kathode* in caustic soda) *after a reversal of the current.* The liquid seems to be a compound of oxygen and hydrogen, presumably hydroxyl.

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10. *On the Electro-deposition of Alloys.* *By* Professor SILVANUS P. THOMPSON, *D.Sc.*

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11. *On the Action of the Solvent in Electrolytic Conduction.* *By* T. C. FITZPATRICK, *B.A.*

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12. *On the Industrial Electro-deposition of Platinum.* *By* Professor SILVANUS P. THOMPSON, *D.Sc.*

MONDAY, SEPTEMBER 5.

The following Papers and Reports were read:—

1. *On the Princeton Eclipse Expedition.* *By* Professor C. A. YOUNG, *Ph.D., LL.D.*

Origin of Expedition.—The expedition had its origin in the desire of the author to verify and re-examine the question of the existence of the so-called 'reversing layer' at the surface of the sun—a question of special interest to himself, as the

[1] This is a continuation of experiments described by Messrs. Lees and R. W. Stewart in the *Proc. Manchester Lit. and Phil. Soc.* Feb. 22, 1887.

belief in the existence of such a stratum has been chiefly based upon an observation made by him in Spain in 1870. The necessary funds for the expedition—the spectroscopic part of it—were provided by the liberality of certain friends of the College of New Jersey (commonly known as Princeton College). At first only spectroscopic observations were contemplated; but later Professor Libbey offered to accompany the expedition at his own expense, and look after the photographic operations, provided suitable apparatus could be obtained.

Personnel.—The party consisted of seven persons: Professor C. A. Young, Professor M. McNeill, Professor W. Libbey, Jun., Mrs. Libbey, Miss Boyd, Miss Yeomans, and Mr. F. Fisher, the mechanician of the party.

Instruments.—(*a*) A photographic telescope, loaned by the Navy Department of the United States Government. The instrument has a 6-inch lens by Dallmeyer, with a focal length of about four feet. It was mounted on an equatorial stand with clockwork, and was intended to give a series of pictures of the corona. An ingenious apparatus had been applied by Professor Libbey for exposing the whole series of eleven plates without the necessity of drawing any slides or doing anything likely to disturb the pointing of the instrument. An ordinary camera of large field was also mounted on the same stand and carried by the clockwork—Professor Libbey's instrument.

(*b*) A fixed photographic telescope of 6-inch diameter and 8-feet focus: the lens, however, was not specially corrected for the photographic rays. It was entrusted to us by Professor W. H. Pickering, of Harvard College Observatory, to be used in making a series of pictures for comparison with a second series to be made by a similar instrument in Japan by Professor Todd. It had no mounting or clockwork, but was to be simply blocked up into position and used fixed. The ladies were to manipulate it.

(*c*) A large direct-vision half-prism spectroscope by Hilger, with collimator of about 40 inches focal length, and a prism capable of taking in $2\frac{1}{4}$-inch beam. With the eyepiece used the dispersion is sufficient to show D widely double, and E easily so. The slit is about an inch in length. In front of it was placed an achromatic object-glass of about 2 inches diameter and 18 inches focus, forming on the slit plate a small image of the sun, about one-sixth of an inch in diameter. The instrument was mounted upon a portable equatorial stand, and was in charge of Professor McNeill, to be used in studying the extension of the corona line on the east and west sides of the sun, and in examining the general structure of the corona spectrum with reference to the question of the existence in it of true dark Fraunhofer lines, or bands of other sorts.

(*d*) A 5-inch achromatic telescope of 6 feet focal length, equatorially mounted, and provided with a grating spectroscope. Telescope and collimator of the spectroscope have each a diameter of about $1\frac{1}{2}$ inch, and a focal length of 14. The grating, by Rutherfurd, has 17,280 lines to the inch, the ruled space being $1\frac{3}{4}$ inch by $2\frac{1}{4}$ nearly.

In the eyepiece was placed a scale made by photographing a small portion of the map of the spectrum just below F, including certain groups of lines which Mr. Lockyer has pointed out as specially adapted to throw light on the questions involved by their behaviour at the beginning and end of totality.

The instrument also had attached to it a small integrating spectroscope of one-prism dispersion, with which the general corona spectrum could be observed at the middle of totality.

It was not thought best under the circumstances to attempt any spectrum-photography, as we expected that to be provided for by European parties.

Station, &c.—The station selected for us was a country house about eight miles north-east of the town of Rschew, a city of some 30,000 inhabitants, at present the terminus of a railway which branches off at Ostaschkowo from the main line between Petersburg and Moscow. Our lat. was 56° 22′; long. 16m. 04s. east of Pulkowa. The station was selected and all arrangements made for us by Dr. Struve, the director of the Pulkowa Observatory, to whom we are indebted to an extent not easily to be expressed in words. Our instruments were passed through the Custom House free of duty and without examination, and were forwarded to our

station without any trouble to us. The War Department detailed an officer of Engineers—Captain Witkowski—who with his orderly preceded us to our station, made all needed arrangements there, and made all the desirable observations for the determination of accurate time. To him we are under the greatest obligations.

Observations of the Eclipse.—The weather was cloudy during the whole time except for a few moments about half an hour after the totality, when for a minute or two the disc of the sun, partly covered by the moon, was visible between and through the clouds. Of course all spectroscopic and photographic observations were rendered entirely impossible.

We hoped to be able to determine the duration of totality with some accuracy notwithstanding the clouds, but it was found impossible to fix the moment when totality began nearer than ten seconds or so, the diminution of the light having been unexpectedly gradual. The end of totality, on the other hand, was much more sharply marked, the observations of Captain Witkowski, Professor McNeill, and myself all agreeing within a single second.

The darkness, also, was far less intense than had been expected. It was possible to read fine print even when it was darkest, and I noticed that the sash-bars in the window of a building some 400 or 500 feet away remained discernible through the whole totality.

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2. *Observations of Atmospheric Electricity.* *By* Professor LEONTI WEBER.

I will try to give a short report of some experiments I have made during the last year with regard to atmospheric electricity. It was formerly uncertain whether the electrostatic potential would increase on going from the surface of the earth to more elevated regions of the atmosphere or not; whether the potential in a normal (*i.e.*, cloudless) state of the atmosphere was always positive or sometimes negative. Sir William Thomson was the first to show, by exact methods of measurement, that the increase of the potential with the elevation is very important, and amounts to about 100 volts per mètre. Afterwards the fact was proved by many other observers, especially lately by Mr. F. Exner at Vienna, who found an increase of sixty to six hundred volts per mètre. These observations were made by means of an electrometer. In consequence of many inconveniences which are connected with the use of an electrometer, I have tried the measurements with a very sensitive galvanometer. In this case it is necessary to apply an aspirating or exhausting apparatus—for example, a flame or a system of points—to the upper end of the conductor, which is elevated in the atmosphere. In order to get a constant apparatus I have used 400 of the finest needles inserted in a metallic ribbon. This system I have raised in air by means of a captive balloon, or by a kite which was attached to a conducting string, or to a twisted line of the finest steel wire. In this way the greatest height to which I have raised the points has been one to three hundred mètres. When the lower end of the kite line was communicating with a galvanometer whose other pole was in contact with the earth, a current passed through the galvanometer. For determining the strength of this current I propose to call mikro-milliampère the 10^{-9} part of an ampère. At the height of 100 mètres, in the average, the current begins to be regular, and increases to 4,000 or 5,000 of those units until the height of 300 mètres is reached. The increase is very regular, and seems to be a linear function of the height. I have nevertheless found that the smallest quantities of dust contained in the atmosphere, or the lightest veil of cirrus, disturbed the measurements very materially, and generally made the potential lower or negative. Experiments of this nature I have made at Breslau and at the top of the Schneekoppe in the 'Riesengebirge.' Especially at the last station an increase of potential was observed, not only by reason of the perpendicular height, but also by reaching such regions of the atmosphere as were situated horizontally to about 200 mètres from the outmost steep top of the Schneekoppe.

Therefore it must, according to Mr. Exner, be assumed that the surface of the earth represents a surface of equal potential, and that the consecutive surfaces of higher potential are stretched parallel over the plane countries of the earth and

lie closer together over all the elevated points—as, for example, mountains, church towers, &c. On the basis of these facts I think it easy to explain the electricity of thunderstorm clouds. In fact every cloud, or every part of a cloud, may be considered as a leading conductor, especially such clouds as have for the most part perpendicular height. After being induced the charge results by supposing a 'convection' of electricity either from the upper or from the lower side, according to greater or smaller speed of the air in the height. In the first case, the clouds will be charged with positive electricity; in the other, with negative electricity.

I am inclined, therefore, to state that the electricity of thunderstorm clouds must be considered as a special but disturbed case of the normal electric state of the atmosphere, and that all attempts to explain the thunderstorm electricity must be based on the study of the normal electricity of the atmosphere.

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3. *The General Bibliography of Meteorology and Terrestrial Magnetism. Compiled by the Signal Office at Washington. By* CLEVELAND ABBE.

The rapid increase of the literature of the sciences makes a complete index to the published memoirs for each special department a matter of the greatest importance to the student, and equally so to the practical man. The astronomical bibliographies of Struve and Houzeau and Lancaster, and the great Index-catalogue of the library of the Surgeon-General's Office, by Billings, are examples of the high esteem in which special bibliographies are held; and if the Signal Office does not emulate the exhaustive character of these monumental labours, it has at least attempted to compile an index to the literature of meteorology that shall have practical value and realise a desideratum that has long been felt by the younger students of the science of meteorology.

The urgent need of an index to the literature of meteorology was expressed at the general congresses of meteorologists at Vienna and Rome, and a special committee on this subject was appointed by the International Meteorological Committee in 1880. Mr. Hellmann and Mr. Scott composed this committee, and the principal results of their deliberations were, first, the discovery of the fact that much work had already been accomplished by private effort, and, second, a great stimulus given to the whole subject, based on the evident possibility of making a successful combined effort. The final conclusion of the committee was to the effect that, for the present, it was best to secure from each country the publication of a bibliography of its own literature in the department of meteorology.

While the committee were still considering the subject, General W. B. Hazen, who had succeeded General Myer as the chief signal officer, decided that the daily needs of the weather bureau at Washington justified the compilation of a general bibliography covering all the subjects in which that office was interested. With the permission of the Secretary of War he therefore obtained a copy of the card catalogue compiled by Mr. Symons of London, on which copy that gentleman kindly spent great labour towards its perfection, and of the card catalogue that I had compiled by selection of titles from the great index of the Royal Society. With this as a nucleus, General Hazen authorised letters to be sent inviting the co-operation of all weather bureaux, observatories, and authors, in the preparation of a complete general bibliography. The responses to these requests have been most gratifying, and with these manuscript collections have been incorporated all accessible printed lists of titles. The more important series of periodicals have been examined anew, and special searches have been made in the libraries of Europe and America for pamphlets and rare publications.

The resulting index now contains over fifty thousand titles of works, written by over twelve thousand authors. The cards are arranged by subjects with full author index; the classification by subjects includes over one hundred and sixty subdivisions, covering general meteorology, climatology, dynamic meteorology, the theory of instruments, history and bibliography, special storm studies, weather prediction, observations, and a rather full list of subjects intimately connected with meteorology proper, such as the relations of the atmosphere to animal and vegetable life, disease, &c.

In the compilation of this index over three hundred authors, weather bureaux, and libraries have most heartily contributed; nearly every nation in the world has cheerfully responded to the call for information. The bibliographer, Mr. C. J. Sawyer, and his clerks have been employed continuously for three years, and in a few months the question will be submitted to the national government whether such an index is not worth publishing in full for the benefit of the whole world. It has become, in fact, an international work, and its publication is the only means by which a fair return can be made to co-operating scientists, and by which it can be assured against destruction by fire or accident.

At present a small case of drawers contains these fifty thousand cards. Whoever wishes to know what has been written on a given subject has but to consult the proper drawer and section, and the response comes quickly and fully. The information is as often desired by practical men as it is by the students and the professors; to them all it is, like the *index rerum*, an indispensable working tool. It does not seem likely that any publisher will be able to print such a bibliography at a price that will bring it within the reach of the students who need it the most. Every similar work that has been successful has been compiled, and, at least in part, published with Government aid, and we hope that the Congress of the United States will make this important international work of the Signal Office as freely available as are its daily weather predictions, its monthly weather reviews, its international maps, and other publications.

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4. *Fourth Report of the Committee appointed to co-operate with Mr. E. J. Lowe in his project of establishing on a permanent and scientific basis a Meteorological Observatory near Chepstow.*—See Reports, p. 39.

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5. *Second Report of the Committee appointed to co-operate with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.*—See Reports, p. 34.

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6. *On the Hygrometry of Ben Nevis.* *By* H. N. Dickson.

This paper gives an account of observations which were undertaken for the purpose of testing the applicability at high-level stations, such as Ben Nevis Observatory, of existing tables and formulæ for calculating the dew-point and humidity from the readings of wet and dry bulb thermometers. The construction of the direct hygrometer used, that of Professor Chrystal, is described, and the action of the wet and dry bulbs under different meteorological conditions is examined in considerable detail; the results showing that for investigations of this kind a great range of humidity is necessary, the indications of the wet and dry bulbs being very uncertain when the difference between them is small.

The reduction of the observations is performed in the first place by a graphic method, from which the following expression is deduced:—

$$f' - f'' = (t - t')\,k,$$

f' being the vapour pressure at the temperature t' of the wet bulb, f'' that at the temperature of the dew-point, and t the air temperature.

The truth of the above equation being assumed, the values of the quantity k are next found by direct calculation from the observations. The available observations—numbering in all about 300—make it possible to give fairly approximate values for each degree of temperature of the wet bulb from 13° to 45° F. A sudden large change takes place at the freezing-point and a similar, though much smaller, discontinuity is shown to occur when the wet bulb stands between 39° and 40° F. Below 32° F. the quantity $1/k$ appears steadily to increase from 26 to 61, while between 32° and 39° F. and from 40° F. upwards its values remain nearly constant at about 96 and 111 respectively.

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7. *On the Thermal Windrose at the Ben Nevis Observatory.* *By* ANGUS RANKIN.

The direction of the wind and the temperature of the air form two of the meteorological elements observed and recorded hourly at the Ben Nevis Observatory. When making observations, the directions of the wind are referred to the thirty-two points of the compass; but in computing the results, which are briefly described in this paper, the directions were referred to eight points only—namely, N., N.E., E., &c. All the remaining points were taken into account by annexing them in the usual way to these octants. The temperature of the air was that indicated by compared thermometers, protected in Stevenson screens, with their bulbs at the standard height of 4 ft. above the surface of the ground or the snow. In calculating the mean temperature of the eight directions of wind, the thermometer readings were tabulated under the directions of wind observed at the same hours, or under their octants, and the mean taken for each direction for the different months, for the year, and for the seasons. The observations so treated were those of the three years ending May 1887; and the results here discussed are on the mean of these years.

These results show that the south wind has the highest yearly mean temperature—namely, 32°·6, and the north-east the lowest—namely, 26°·5. In each of the seasons the north-east wind is the coldest, and with one exception the south is the warmest, the exception being winter, when the warmest is the south-west. The point having the highest mean temperature does not remain the same throughout the months, but oscillates considerably. This point during the winter months is south-west, but as the year advances it swings round through south to south-east, which is its direction in July and September. The coldest point has not so marked an oscillation. The explanation of this oscillation in the direction of the warmest wind is that the south-east wind blows over land and the south-west over sea—land areas being subject to greater extremes of temperature than sea areas. The annual range in mean monthly temperature is greatest for south-east winds, being 24°·3, and least for north-west winds, being 14°·4. The difference between the warmest and coldest winds varies from month to month, the greatest difference being 10°·7 in March, and the least 4°·2 in April, while the mean of all the differences is 6°·7. The wind having the highest mean monthly temperature is the south-east, its temperature in July being 44°·0; and that having the lowest is the north-east, its temperature in March being 18°·2. The winds arranged in their order of highest yearly mean temperature, with their respective temperatures, are:—

S.	S.W.	W.	N.W.	S.E.	E.	N.	N.E.
32°·6	32°·5	31°·4	30°·2		27°·8	27°·6	26°·5

the north-west and south-east being equal—a curious fact, seeing, as has already been noticed, that they differ so much in annual range. Each of the directions S., S.W., W., and N.W. attains its minimum temperature in January, and each of the directions N., N.E., E., and S.E. in March. All the directions except N.E. and N.W. have their maxima in July, the two exceptions occurring a month later.[1]

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8. *On a Peculiarity of the Cyclonic Winds of Ben Nevis.* *By* R. T. OMOND.

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9. *Final Report of the Committee appointed to co-operate with the Meteorological Society of the Mauritius in the publication of Daily Synoptic Charts of the Indian Ocean for the year* 1861.—See Reports, p. 40.

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[1] See *Proc. Roy. Soc.* Edin. 1886–87.

10. *On the Effect of Continental Lands in altering the Level of the adjoining Oceans.* *By* Professor EDWARD HULL, *LL.D., F.R.S.*

The effect of the attraction of continental land upon the oceanic waters adjoining seems to have been very much overlooked by British physical geographers. That some slight effect arises in the direction of elevating the surface of the ocean in proximity to the coast is generally admitted, but the amount of rise is considered to be small, perhaps insignificant. The prevalence of these views was attributed by the author to the widespread influence of Lyell's hypothesis of the uniformity of the ocean-surface all over the globe.

The author's attention had been called to the subject by the perusal of the works of the German geographers Suess [1] and Fischer,[2] especially the latter; and he had received great assistance in his investigations from Professor G. G. Stokes, Pres. R.S., and from the Rev. Maxwell H. Close, F.G.S., which assistance he gratefully acknowledged.

In attempting to determine the relative levels of the ocean surface along the margins of continents as compared with those of mid-oceanic islands, the German authors above quoted had based their results on observations of the length of the second's pendulum. Many years ago (1849) Stokes had shown that the force of gravity must be greater in such islands than on continental stations,[3] and this conclusion corresponded with actual observations on the length of the second's pendulum at stations all over the globe as collected by Airy.[4] The formula of Suess and Fischer based on these was to the effect that the difference in the level of the ocean between two such stations was found in *mètres* by multiplying the difference in the number of daily oscillations in the second's pendulum by 122. This in the case of the stations of California (or Mexico?) in lat. 21° 30′ and of the Sandwich Islands would amount to 4,520 feet; a very startling result if correct.

The author proceeded to discuss the effect of continental lands, showing that this was in the first instance divisible under two principal heads: The effect (1) of the unsubmerged, and (2) of the submerged masses. In the former case, where the mass rose above the surface, one component of the attraction acted in a more or less vertical direction; in the second case, all in a lateral direction; but both had the effect of elevating the surface of the ocean. The horizontal distance to which the vertical effect extended owing to the curvature of the earth's surface was then considered; and it was shown that, where continental lands rise from a deep ocean, the effect of the lateral attraction far exceeds that of the vertical attraction of the unsubmerged mass. Professor Stokes had furnished the author with a hypothetical case, in which the elevation of the ocean was estimated to reach 400 feet above the mean geodetic surface of the earth.

For the purposes of illustration three cases were selected, viz.:—

(1) The table-land of Mexico, between lats. 18° and 26° N.
(2) The table-land of Bolivia, " 19° and 26° S.
(3) The Andes of Chile, " 26° and 35° S.

The mean elevations, distances from the ocean, and extent having been determined, and the mean density being taken at 2·6 for emergent, and 1·6 for submerged land, the results of the attraction of the mountain masses in each case were as follows:—

(1) Mexico, 230 feet; (2) Bolivia, 301 feet; (3) Chile, 63 feet; the elevations being calculated above a mean geodetic surface.

To the above results, due to the gravitation-potential of the elevated masses, were to be added those due to the following factors:—

(*a*) The marginal plain or emergent tract on either side of the mountain mass.
(*b*) The high lands both to the north and south of the special sections above dealt with.
(*c*) And lastly, and most important, the submerged continental mass.

[1] Suess, *Das Antlitz der Erde* (1887).
[2] Fischer, *Untersuchungen über die Gestalt der Erde* (1886).
[3] Stokes, *Cambridge Philosophical Transactions*, vol. viii. pp. 672–695.
[4] Airy, 'On the Figure of the Earth,' *Encyclop. Metropolitana.*

To provide for the sphericity of the earth deductions of various amounts, according to circumstances, were made from the numbers obtained from the formula which Mr. Close had arrived at by a double process, and which is given at length in the paper itself.

Combining these results with those given above, we obtain as the whole rise of the ocean surface as follows:—

(1) Mexico, 780 feet; (2) Bolivia, 2,150 feet; (3) Chile, 1,580 feet.

In all the above cases the coast was taken as descending to a depth of 15,000 feet at a gradient of about $\frac{1}{44}$ to $\frac{1}{50}$, the comparatively low results in the case of Chile being due to the narrowness of the mountain range, 30 miles in mean breadth, as compared with 300 miles in the case of Bolivia.

The above results, which are probably rather under than over estimates, fall considerably short of those to be drawn from Suess and Fischer's formula, but are probably much in excess of the views held by British physical geographers generally; and the conclusion was drawn, that if the same processes of reasoning and calculation were applied to all parts of the world, it would be found that the ocean waters were piled up to a greater or less extent all along our continental coasts, producing very important alterations in the terrestrial configuration as compared with an imaginary ellipsoidal, or geodetic, surface, to which all these changes of level must necessarily be referred.

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11. *On some Variations in the Level of the Water in Lake George, New South Wales. By* H. A. Russell.

This paper refers to certain changes in the level of the water of Lake George, as shown by the recording machine placed there. They consist:—

(1) Of changes in the level of the water similar to those which have been observed at the Lake of Geneva and other places with variations not yet accounted for.

(2) Of changes in level lasting several hours, for which no cause is apparent, but which the author thinks may result from changes in the vertical like those observed by Professor Darwin, M. D'Abbadie, and others. Reference is made to the annual change in the level errors at Greenwich, Sydney, and other places, the period of which coincides with that of the solstices, and to other changes in it perhaps connected with those in the lake.

(3) Of a diurnal change in level, not coincident with ocean or atmospheric tides. In this change the water rises to its maximum at the south end of the lake at noon, and its minimum at midnight. The amount of change varies, but does not seem to be affected by the position of the moon.

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12. *On the different kinds of Thunderstorms, and on a Scheme for their Systematic Observation. By the* Hon. Ralph Abercromby, *F.R.Met.Soc.*

The author shows that there are at least three distinct types of thunderstorm in Great Britain.

The first, or 'squall thunderstorms,' are simply squalls associated with thunder and lightning, which fly nearly with the surface wind. These form on the sides of primary cyclones.

The second, or 'secondary thunderstorms,' are associated with secondary cyclones. These move against the surface-wind, and are very rarely accompanied by squalls. Very little is known of the nature of these storms, though they are the commonest type of thunder in Great Britain.

The third, or 'line thunderstorms,' are apparently of a totally different nature. They take the form of long narrow bands of rain and thunder—perhaps one hundred miles long, and only five or ten broad, which cross the country rapidly nearly broadside on. These are usually preceded by a very violent squall. The squall which capsized the 'Eurydice' was of this type. The air in line thunderstorms seems to circulate round a long horizontal axis—which would lie in the direction

of the length of the storm—instead of round a short nearly vertical axis, as in cyclones.

The outline is given of a proposed scheme for the systematic observation of thunderstorms in England, by which it is hoped that the mechanical nature of the circulation of the air in every kind of thunderstorm may be discovered. It is also shown that if that particular kind of thunderstorm which is not associated with any distortion of isobaric lines can be worked out, a kind of rain could then be successfully forecast which is now very rarely announced. Forecasts now have to depend almost exclusively on synoptic charts of isobaric lines. When these fail, they fail; but it is hoped that observations on the form and motion of clouds may be found to indicate the approach of rain when the barometer shows nothing.

Mathematical Sub-Section.

1. *On the Criteria for Discriminating between Maxima and Minima Solutions in the Calculus of Variations.* *By* E. P. Culverwell, *M.A.*

The paper explained the mode of finding the criteria for all known classes of problems, provided the limits be fixed, and when the limits are not fixed, the nature of problem to be solved was indicated. There are four classes of problems.

I. To make $U=\iint \ldots \int f(x_1, x_2, \ldots x_m, y_1, y_2, \ldots y_n)dx_1 dx_2 \ldots dx_m$ a maximum, f representing a function including differential coefficients of the y's by the x's.

II. Suppose V, W, &c., to represent integrals of the same character as U, we may be required to make F(U, V, W . . .) a maximum where F represents a function of known form, and the $y_1, y_2, \ldots y_n$ occurring in U, V, W, . . . are the quantities whose form is to be determined.

III. It may be required to make U a maximum subject to the condition V = constant; or, more generally, a similar restriction may be applied to problem II., modifying it as this problem modifies I.

IV. It may be required to make U a maximum when the variables x_1, $x_2 \ldots x_m, y_1, y_2, \ldots y_n$ are connected by one or more algebraic or differential equations, or this restriction may be introduced in problems II. and III.

In all these cases the criteria consist of two parts: 1st. There is a condition or set of conditions which must be satisfied for every possible set of values of the independent variables within the limits of integration. 2nd. The limits of integration must satisfy certain conditions.

The first set of conditions is obtained, without any algebraic transformations, by taking an infinitely small range of integration and showing that, when the limits are fixed, only the 'highest differential coefficients' of the variations need be retained, both in the integrals and in the equations of connection. A full account of the method of comparing the orders of magnitude of the variations may be found in the 'Transactions of the Royal Society,' vol. 178, p. 95; but for the simple case in which there is but one independent variable, all we need to do is to point out that, because

$$\frac{d^r\delta y}{dx^r}=\int\frac{d^{r+1}\delta y}{dx^{r+1}}dx,$$

$\frac{d_r\delta y}{dx^r}$ must be infinitely small compared to $\frac{d^{r+1}\delta y}{dx^{r+1}}$ when the limiting value of $\frac{d^r\delta y}{dx^r}$ is zero, and the range of integration is infinitely small. Now, when the 'limits are fixed' the limiting values of all the variations appearing outside the sign of integration in the most reduced form of the first variation (the form which enables us to determine the value of y giving the maximum) must be zero, and therefore they must all be infinitely small compared with the variation of the highest differential coefficient appearing in the function to be integrated. Hence the value of the second

variation can only differ infinitely little from the value we obtain by neglecting all the variations but that of the highest differential coefficient of y in the integral. It is necessary to justify this reasoning by inquiring into the conditions of continuity which must be satisfied by the variations. The conditions are not explicitly given in the statement of the problem, but are implied in the method of obtaining and reducing the first variation. The problem fully stated is, to make an integral greater than any other integral which can be derived from it by a change in which the variations of all the dependent variables and their fluxions appearing in the integral are infinitely small, and *all but the highest fluxions of the variables* are continuous.

The application of this principle to II. is as follows. Suppose it is required to make $\lambda = F(U, V)$ a maximum, where

$$U \equiv \int f\left(x, y, \frac{dy}{dx}, \ldots \frac{d^n y}{dx^n}\right)dx \equiv \int f(x, y, \dot{y}, \ldots y^{(n)})dx \equiv \int u dx,$$

with similar expressions for V. Then, $\delta^2\lambda$ being the second variation of λ

$$2\delta^2\lambda = \frac{d^2F}{dU^2}\left[\int \delta u dx\right]^2 + 2\frac{d^2F}{dUdV}\int \delta u dx \int \delta v dx + \frac{d^2F}{dV^2}\left[\int dv dx\right]^2 + \frac{dF}{dU}\int \delta^2 u dx + \frac{dF}{dV}\int \delta^2 v dx$$

in this expression δu includes such terms as $\frac{du}{dy^{(r)}}\delta y^{(r)}$, and taking an infinitely short range of integration, we have proved that we may neglect $\delta y^{(r)}$ in comparison with $\delta y^{(n)}$, where $r<n$. Hence we retain only the terms

$$\frac{d^2F}{dU^2}\left[\int \frac{du}{dy^{(n)}}\delta y^{(n)}dx\right]^2 + \&c. + \frac{dF}{dU}\int \frac{d^2u}{dy^{(n)2}}\delta y^{(n)2}dx + \frac{dF}{dV}\int \frac{d^2v}{dy^{(n)2}}\delta y^{(n)2}dx.$$

Now since the range of integration is infinitely small $\left[\int \frac{du}{dy^{(n)}}\delta y^{(n)}dx\right]^2$ is infinitely small compared to $\int \delta y^{(n)2}dx$, the former being of the order $\delta y^{(n)2}(x_1 - x_0)^2$ and the latter of the order $dy^{(n)2}(x_1 - x_0)$, x_1 and x_0 being the limits of integration. Hence we need only retain the terms

$$\frac{dF}{dU}\int \frac{d^2u}{dy^{(n)2}}\delta y^{(n)2}dx + \frac{dF}{dV}\int \frac{d^2v}{dy^{(n)2}}\delta y^{(n)2}dx,$$

the sign of which when the integration is small is evidently the same as that of

$$\frac{dF}{dU}\frac{d^2u}{dy^{(n)2}} + \frac{dF}{dV}\frac{d^2v}{dy^{(n)2}}.$$

Therefore, for a sufficiently short range of integration λ is a maximum or minimum, according as this quantity is negative or positive.

This result can be extended so as to apply to any case, however complicated.

The simplest case of problem III. is to make U a maximum subject to $V = C$, U and V having the meanings above given. The ordinary method of obtaining the equation giving y in terms of x is to equate $\delta(U + \mu U)$ to zero, μ being determined from the condition $V = C$. A process just similar to that employed in II. leads to the result that, when the range of integration is small, the integral U is a maximum or a minimum according as the sign of $\frac{d^2u}{dy^{(n)2}} + \mu\frac{d^2v}{dy^{(n)2}}$ is negative or positive. The general result is similar in character.

The simplest case of problem IV. is to make U a maximum subject to the condition $v = o$ where

$$U \equiv \int u dx \equiv \int f\left(x, y, z, \frac{dy}{dx}, \frac{dz}{dx}, \ldots \frac{d^n y}{dx^n}, \frac{d^n z}{dx^n}\right)dx$$

and v is a function similar to u. To find y and z as functions of x, the ordinary method is to equate $\int(\delta u + \mu\delta v)dx$ to cipher. By this means the value of μ is

obtained as a function of x, and the second variation, when we leave out all small terms, becomes, for an infinitely small range of integration,

$$\tfrac{1}{2}\int\left\{\left(\frac{d^2u}{dy^{(n)2}}+\mu\frac{d^2v}{dy^{(n)2}}\right)\delta y^{(n)2}+2\left(\frac{d^2u}{dy^{(n)}dz^{(n)}}+\mu\frac{d^2v}{dy^{(n)}dz^{(n)}}\right)\delta y^n\delta z^{(n)}\right.$$
$$\left.+\left(\frac{d^2u}{dz^{(n)2}}+\mu\frac{d^2v}{dz^{(n)2}}\right)\delta z^{(n)2}\right\}dx,$$

or say $\frac{1}{2}\int(A\delta y^{(n)2}+2B\delta y^{(n)}\delta z^{(n)}+C\delta z^{(n)2})dx$, and the equation $\delta v=0$ becomes

$$\frac{dv}{dy^{(n)}}\delta y^{(n)}+\frac{dv}{dz^{(n)}}\delta z^{(n)}=0,$$

so that eliminating $\delta z^{(n)}$ from the integral we get as the result that U is a maximum or a minimum for a very short range of integration, according as

$$A\left(\frac{dv}{dz^{(n)}}\right)^2 \quad 2B\frac{dv}{dy^{(n)}}\ \frac{dv}{dz^{(n)}}+C\left(\frac{dv}{dy^{(n)}}\right)^2$$

is negative or positive.

If in v there had been no higher fluxions than $\frac{d^{n-2}y}{dx}$ and $\frac{d^{n-2}z}{dx^{n-2}}$, the above expression need only be changed by writing for $\frac{dv}{dy^{(n)}}$ and $\frac{dv}{dz^{(n)}}$, where they appear explicitly, $\frac{dv}{dy^{(n-2)}}$, and $\frac{dv}{dz^{(n-2)}}$, and putting zero instead of both where they appear implicitly in A, B and C. If in u and v, the highest fluxions be $y^{(r)}$ and $z^{(s)}$, and $y^{(p)}$, $z^{(q)}$ respectively, and $r-p>s-q$, then the determining expression becomes $\frac{d^2u}{dy^{(r)2}}$. Where there are more variables and more equations of connection, some patience is required to determine which terms must be retained, but the general principle is exactly the same.

The method of deriving from these criteria the additional criteria necessary, when the range of integration is not small, is fully discussed in the paper quoted, article 16, at least for the problems coming under class I., and it is quite easy to see that the discussion is perfectly general. Owing to the limited space available for the Abstract, it is impossible to include any account of it.

When the limits are not fixed, there is no difficulty in determining the criteria, provided there is but one independent variable. But in the case of multiple integrals, the variability of the limits gives rise to a problem of an entirely new character. When, as is certainly often the case, the solution of the problem is obtained in a form containing arbitrary functions of known quantities, the problem depends on one of the following type. To find the form of ψ so that

$$\int_{x_0}^{x_1}[A\psi(f_1)\delta.\psi(f_1)+B\psi(f_2)\delta.\psi(f_2)]dx$$

shall vanish independently of the form of $\delta\psi$. In this expression f_1 and f_2 are known functions, and of course $\delta.\psi(f_1)$ is the same function of f_1 as $\delta.\psi(f_2)$ is of f_2.

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2. *Some Notice of a new Computation of the Gaussian Constants. By* Professor J. C. ADAMS, *F.R.S.*

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3. *On the Umbral Notation. By the* Rev. ROBERT HARLEY, *M.A., F.R.S.*

The germs of the system of notation proposed in this paper will be found in Sir James Cockle's paper on Hyperdistributives, printed in the 'Philosophical Magazine' for April 1872; but the author is alone responsible for the form in which the subject is here presented. He has endeavoured to develop and extend

the fundamental conception, and to show that the system may be employed with advantage in determining both critical and criticoidal forms of all degrees.

In the usual expansion of the binomial $(x+y)^n$ introduce x^0 and y^0 and change indices into suffices: we thus obtain:—

$$x_n y_0 + n x_{n-1} y_1 + \frac{n(n-1)}{1\cdot 2} x_{n-2} y_2 + \ . \ . \ . \ + \frac{n(n-1)}{1\cdot 2} x_2 y_{n-2} + n x_1 y_{n-1} + x_0 y_n,$$

in which $x_0, x_1, x_2 \ . \ . \ . \ x_n$ and $y_0, y_1, y_2 \ . \ . \ . \ y_n$ may be regarded as independent arbitraries, and may therefore be replaced by any functions or forms we please. Let this expression be represented for shortness by the binomial $(x+y)_n$; then the symbols x and y may be called *umbræ*, and the symbols $(x+y)_n$, x_r, y_r, *potences*. An umbra is a mere recipient of suffices, being otherwise uninterpretable; but in the particular case $x_r = x^r$, which will often occur, x may be called a *radix*. Radices are not necessarily algebraical functions; they may represent operations as well as quantities, subject only to the index law $x^m y^n = x^{m+n}$. If x be an umbra and y a radix, the development of $(x+y)_n$ will be

$$x_n + n x_{n-1} y + \frac{n(n-1)}{1\cdot 2} x_{n-2} y^2 + \ . \ . \ . \ + \frac{n(n-1)}{1\cdot 2} x_2 y^{n-2} + n x_1 y^{n-1} + x_0 y^n.$$

The denumerate form

$$x_n y_0 + x_{n-1} y_1 + x_{n-2} y_2 + \ . \ . \ . \ + x_2 y_{n-2} + x_1 y_{n-1} + x_0 y_n,$$

in which x and y are both umbral, may be obtained directly from the expansion of $(x+y)_n$ by simply suppressing the factors containing n: this form may be represented, in accordance with the quantical notation, by $(x+y\rangle_n$. If $x+y$ be penumbral, that is to say, if one of the symbols, x, be an umbra, and the other, y, a radix, then $(x+y\rangle_n$ will represent

$$x_n + x_{n-1} y + x_{n-2} y^2 + \ . \ . \ . \ + x_2 y^{n-2} + x_1 y^{n-1} + x_0 y^n.$$

Writing n_r for $\dfrac{n!}{(n-r)!\,r!}$, we have $(x+y)_n = (x+ny\rangle_n$, provided that, in the development of the dexter, we interpret n_0 by 1. In like manner we have $(x-y)_n = (x-ny\rangle_n = x_n y_0 - n_1 x_{n-1} y_1 + n_2 x_{n-2} y_2 -$ &c.; where the signs connecting the monomials are + and − alternately, and the general or rth term is

$$(-)^{r+1} n_{r-1} x_{n-r+1} y_{r-1}.$$

Two peculiarities in these forms deserve notice. One is that in the potence representation $(x \pm ny\rangle_n$, the n inside the brackets is umbral, and the n outside is quasi-numerical. The other is that in developing such a potence as $(x\pm y)_{m+n}$, or its equivalent $(x \pm \overline{m+n}\,.\,y\rangle_{m+n}$, the factors $(m+n)_1$, $(m+n)_2$, &c., are not to be expanded as potences; for $(m+n)_r$ is simply what n_r or $\dfrac{n!}{(n-r)!\,r!}$ becomes when for n we substitute $m+n$; that is to say

$$(m+n)_r = \frac{(m+n)!}{(m+n-r)!\,r!}.$$

There is no difficulty in extending the notation to any number of symbols. Thus

$$(x+y+z)_n = (x+y)_n z_0 + n_1 (x+y)_{n-1} z_1 + n_2 (x+y)_{n-2} z_2 + \text{\&c.},$$

and the full development is obtained by expanding the binomials. Similarly

$$\begin{aligned}
(x+y+z\rangle_n &= (x+y\rangle_n z_0 + (x+y\rangle_{n-1} z_1 + (x+y\rangle_{n-2} z_2 + \ . \ . \ . \ (x+y\rangle_2 z_{n-2} \\
&\qquad + (x+y\rangle_1 z_{n-1} + (x+y\rangle_0 z_n \\
&= x_n y_0 z_0 + x_{n-1} y_1 z_0 + x_{n-2} y_2 z_0 + \ . \ . \ . \ + x_2 y_{n-2} z_0 + x_1 y_{n-1} z_0 + x_0 y_n z_0 \\
&\quad + x_{n-1} y_0 z_1 + x_{n-2} y_1 z_1 + x_{n-3} y_2 z_1 + \ . \ . \ . \ + x_2 y_{n-3} z_1 + x_1 y_{n-2} z_1 + x_0 y_{n-1} z_1 \\
&\quad + x_{n-2} y_0 z_2 + x_{n-3} y_1 z_2 + x_{n-4} y_2 z_2 + \ . \ . \ . \ + x_2 y_{n-4} z_2 + x_1 y_{n-3} z_2 + x_0 y_{n-2} z_2 \\
&\quad + x_2 y_0 z_{n-2} + x_1 y_1 z_{n-2} + x_0 y_2 z_{n-2} + x_1 y_0 z_{n-1} + x_0 y_1 z_{n-1} + x_0 y_0 z_n.
\end{aligned}$$

By this process any polynomial, whether umbral or penumbral, may be developed. Analogy requires that $(x+y)_0$ or $(x+y\curvearrowleft)_0$ be interpreted by x_0y_0, $(x+y+z)_0$, or $(x+y+z\curvearrowleft)_0$ by $x_0y_0z_0$, and so on.

The author shows how readily this system of notation lends itself to the determination of both critical and criticoidal forms. By *critical forms* are meant those algebraical functions which remain unchanged when one of the variables is augmented or diminished by any assignable quantity. As the leading coefficients of covariants they are sometimes called seminvariants, being reduced to zero by one only of the operators which reduce to zero an invariant. By *criticoidal forms* are meant those differential expressions which remain unchanged when either the dependent or the independent variable is changed. Such expressions might perhaps be called *seminvaroids*. Criticoids which are unaffected by a change of the dependent variable the author proposes to call *decriticoids*, and those which are unaffected by a change of the independent variable he proposes to call *incriticoids*. Sir James Cockle, to whom we owe the discovery of these forms, has termed the first class 'ordinary criticoids,' and the second 'differential criticoids'; but in fact both are differential criticoids.

To determine the general form of critical functions, the author considers the effect of the substitution of $x+uy$ for x in the potence $(x+ay)_n$, a being an umbra, and u, x, y radices. Writing A in place of $a+u$, the result obtained is

$$F_r(A) = \left(A - \frac{A_1}{A_0}\right)_r = \left(a - \frac{a_1}{a_0}\right)_r = F_r(a),$$

a formula by means of which critical functions may be calculated with great ease and rapidity. When $r=1$, both sides vanish identically. When $r=2$, 3, &c., critical functions of the second, third, and higher degrees are readily found as follows:—

$$F_2(a) = \frac{1}{a_0}(a_0a_2 - a_1^2),$$

$$F_3(a) = \frac{1}{a_0^2}(a_0^2a_3 - 3a_0a_1a_2 + 2a_1^3),$$

$$F_4(a) = \frac{1}{a_0^3}(a_0^3a_4 - 4a_0^2a_1a_3 + 6a_0a_1^2a_2 - 3a_1^4), \text{ \&c.}$$

Let π be an operator such that

$$\pi a_r = ra_{r-1},\ \pi^2 a_r = r(r-1)\ a_{r-2}, \text{ \&c.};$$

then

$$A_r = (a+u)_r = a_r + r_1a_{r-1}u + r_2a_{r-2}u^2 + \text{\&c.}$$

$$= a_r + u\pi a_r + \frac{u^2}{1\cdot2}\pi^2a_r + \frac{u^3}{1\cdot2\cdot3}\pi^3a_r + \text{\&c.} = e^{u\pi}a_r.$$

And if we extend the meaning of π so as to make it operate on powers and products, thus

$$\pi(a_p^m) = mpa_p^{m-1}a_{p-1},\ \pi(a_pa_q) = a_q\pi a_p + a_p\pi a_q = pa_{p-1}a_q + qa_pa_{q-1}, \text{ \&c.},$$

it is easy to see that when u is infinitesimal

$$\phi(A) = \phi(a) + u\pi\phi(a),$$

where ϕ is integral with respect to a_1, a_2, &c., and π does not operate on a_0 (or, what is the same thing, $\pi a_0 = a_0$). Then, by a process similar to that commonly employed in the proof of Taylor's theorem, it is shown generally that

$$\phi(A) = \phi(a) + u\pi\phi(a) + \frac{u^2}{1\cdot2}\pi^2\phi(a) + \frac{u^3}{1\cdot2\cdot3}\pi^3\phi(a) + \text{\&c.}$$

$$= e^{u\pi}\phi(a).$$

When the coefficients a_0, a_1, a_2, &c., are replaced by a, b, c, &c., respectively, the operator π becomes equivalent to

$$a\delta_b + 2b\delta_c + 3c\delta_d + \&c.,$$

and we recognise in the last result a well-known theorem. When $\pi\phi(a) = 0$ we have $\phi(\mathrm{A}) = \phi(a)$, and the umbral notation enables us to exhibit one form of ϕ, viz.,

$$\phi(a) = \mathrm{F}_r(a) = \left(a - \frac{a_1}{a_0}\right)_r,$$

where r is any positive integral number, not less than 2 and not greater than n, the highest suffix of a.

The notation is next applied to the determination of decriticoids. Any linear differential expression of the nth order,

$$a_0\frac{d^n y}{dx^n} + n_1 a_1 \frac{d^{n-1}y}{dx^{n-1}} + \;.\;.\;.\; + n_1 a_{n-1}\frac{dy}{dx} + a_n y,$$

where a_0, a_1, . . . a_n are functions of x, may be changed into the non-linear form

$$\frac{1}{y}\frac{d^n y}{dx^n} + n_1 a_1 \frac{1}{y}\frac{d^{n-1}y}{dx^{n-1}} + \;.\;.\;.\; + n_1 a_{n-1}\frac{1}{y}\frac{dy}{dx} + a_n,$$

either by dividing by $a_0 y$ and replacing $\dfrac{a_r}{a_0}$ by a_r, or by making $a_0 = 1$ and dividing by y. Write y_r for $\dfrac{1}{y}\dfrac{d^r y}{dx^r}$; then the above non-linear form will be expressed, in the umbral notation, by

$$(y + a)_n.$$

Consider the effect of substituting uy for y in the differential expression, u being any function of x. This substitution being made in $\dfrac{1}{y}\dfrac{d^r y}{dx^r}$, we obtain $\dfrac{1}{uy}\dfrac{d^r(uy)}{dx^r}$, which is readily shown to be equal to $(u + y)_r$, u and y being both umbral. It hence appears that the substitution of $u + y$ for y in the umbral form is equivalent to the substitution of uy for y in the ordinary differential form. Effecting the substitution and expanding, we have

$$(y + u + a)_n = y_n(u + a)_0 + n_1 y_{n-1}(u + a)_1 + \;.\;.\;.\; + n_1 y_1 (u + a)_{n-1} + (u + a)_n,$$

so that, writing A for $u + a$, the changed coefficients are

$$\begin{aligned}
\mathrm{A}_0 &= (u + a)_0 = u_0 x_0 = 1,\\
\mathrm{A}_1 &= (u + a)_1 = u_1 + a_1,\\
\mathrm{A}_2 &= (u + a)_2 = u_2 + 2u_1 a_1 + a_2,\\
\mathrm{A}_r &= (u + a)_r = u_r + r_1 u_{r-1} a_1 + r_2 u_{r-2} a_2 + \;.\;.\;.\; + r_2 u_2 a_{r-2} + r_1 u_1 a_{r-1} + a_r.
\end{aligned}$$

And since $\mathrm{A}_1 - a_1 = u_1$, therefore

$$\frac{d^r \mathrm{A}_1}{dx^r} - \frac{d^r a_1}{dx^r} = \frac{d^r u_1}{dx^r},$$

an equation whose dexter may be developed in terms of u_1, u_2, . . . u_{r+1}. Representing this development by $\theta_{r+1}\,(u)$ the author shows that

$$\theta_r(\mathrm{A}_1) - \frac{d^{r-1}\mathrm{A}_1}{dx^{r-1}} = \theta_r(a) - \frac{d^{r-1}a_1}{dx^{r-1}} + \theta_r(u) - \frac{d^{r-1}u_1}{dx^{r-1}} = \theta_r(a_1) - \frac{d^{r-1}a_1}{dx^{r-1}},$$

a criticoidal relation. In determining the form of θ, two theorems are used, viz.

$$\frac{du_r}{dx} = u_{r+1} - u_1 u_r, \text{ and } \frac{d}{dx}(u - u_1)_r = (u - u_1)_{r+1} - r(u - u_1)_2(u - u_1)_{r-1}.$$

These were given, without demonstration, by Sir James Cockle in his paper on Hyperdistributives.

The former is readily proved; for

$$\frac{du_r}{dx} = \frac{d}{dx}\left(\frac{1}{u}\cdot\frac{d^r u}{dx^r}\right) = \frac{1}{u}\cdot\frac{d^{r+1}u}{dx^{r+1}} - \frac{1}{u}\cdot\frac{du}{dx}\cdot\left(\frac{1}{u}\cdot\frac{d^r u}{dx^r}\right).$$

And a proof of the latter is briefly indicated below: we have

$$(u-u_1)_r=(u+ru_1)_r=\Sigma r_m u_1{}^m u_{r-m},$$

where $r_m=(-)^m\dfrac{r!}{(r-m)!\,m!}$, and the summation extends from $m=0$ to $m=r$, $[r_0=1]$. By the first theorem we have

$$\frac{d}{dx}(u_1{}^m u_{r-m})=u_1{}^m(u_{r-m+1}-u_1u_{r-m})+m(u-u_1)_2u_1{}^{m-1}u_{r-m},$$

and therefore

$$\frac{d}{dx}(u-u_r)_r=\Sigma\{r_mu_1{}^m(u_{r-m+1}-u_1u_{r-m})+mr_m(u-u_1)_2u_1{}^{m-1}u_{r-m}\}.$$

On effecting the summation between the assigned limits $m=0$ and $m=r$, and reducing by means of the relations

$$r_m-r_{m-1}=(r+1)_m, \text{ and } mr_m=-r(r-1)_{r-1},$$

the truth of the second theorem becomes apparent.

By the aid of these theorems it is easy to calculate the non-differential portions of decriticoids. Write U for the penumbral form $u-u_1$, then

$$\frac{dU_r}{dx}=U_{r+1}-rU_2U_{r-1},$$

and by successive differentiations we obtain

$$\theta_2(u)=\frac{du_1}{dx}=u_2-u_1{}^2=(u-u_1)_2=U_2,$$

$$\theta_3(u)=\frac{d^2u_1}{dx^2}=\frac{dU_2}{dx}=U_3-2U_2U_1=U_3,$$

$$\theta_4(u)=\frac{d^3u_1}{dx^3}=\frac{dU_3}{dx}=U_4-3U_2{}^2,$$

$$\theta_5(u)=\frac{d^4u_1}{dx^4}=\frac{d}{dx}(U_4-3U_2{}^2)=U_5-10\,U_2U_3,$$

$$\theta_6(u)=\frac{d^5u_1}{dx^5}=U_6-15\,U_2U_4-10\,U_3{}^2+30\,U_2{}^3, \text{ \&c.}$$

Hence

$$\theta_2(a)=(a-a_1)_2=a_2-a_1{}^2,$$
$$\theta_3(a)=(a-a_1)_3=a_3-3\,a_1a_2+2\,a_1{}^3,$$
$$\theta_4(a)=(a-a_1)_4-3\,(a-a_1)_2{}^2=a_4-4\,a_1a_3-3\,a_2{}^2+12\,a_1{}^2a_2-6\,a_1{}^4,$$
$$\theta_5(a)=(a-a_1)_5-10(a-a_1)_2(a-a_1)_3=a_5-5\,a_1a_4-10\,a_2a_3+20\,a_1{}^2a_3+30\,a_1a_2{}^2-60\,a_1{}^3a_2+24\,a_1{}^5,$$
$$\theta_6(a)=(a-a_1)_6-15\,(a-a_1)_2\,(a-a_1)_4-10\,(a-a_1)_3^2+30\,(a-a_1)_2^3=\text{\&c.}$$

and the law of derivation is obvious.

The umbral notation is equally effective in dealing with incriticoidal forms. Various examples are given in the paper, and the author carries his investigation as far as the determination of the quadrincriticoid, that is to say, the incriticoid of the fourth degree, the degrees of criticoids being the greatest suffices which occur in them respectively. It is proposed to call a decriticoid of the m-th degree an m-ide, and the incriticoid of the m-th degree an m-ine.

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4. *On Criticoids.* *By* ROBERT RAWSON, *F.R.A.S.*

The method proposed in this paper was suggested by a study of the Rev. Robert Harley's paper entitled Professor Malet's Classes of Invariants identified with Sir James Cockle's Criticoids, printed in the 'Proceedings of the Royal

Society,' No. 235, 1884. The case when the dependent variable is changed is first considered. Starting from the two linear differential equations of the n-th order

$$\left(1, P_1, P_2, \ldots P_n\right)\left(\frac{d}{dx}, 1\right)^n y = 0 \quad . \quad . \quad . \quad . \quad (1)$$

$$\left(1, Q_1, Q_2, \ldots Q_n\right)\left(\frac{d}{dx}, 1\right)^n z = 0 \quad . \quad . \quad . \quad . \quad (2)$$

in which the dependent variables are supposed to be connected by the relation:—

$$\log y = \log z + \int (Q_1 - P_1)\, dx \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and introducing a third dependent variable (v), the author obtains two other linear differential equations of the n-th order, viz.—

$$\left(1, R_1, R_2, \ldots R_n\right)\left(\frac{d}{dx}, 1\right)^n v = 0 \quad . \quad . \quad . \quad . \quad (4)$$

$$\left(1, S_1, S_2, \ldots S_n\right)\left(\frac{d}{dx}, 1\right) v = 0 \quad . \quad . \quad . \quad . \quad (5)$$

(4) being connected with (1), and (5) with (2) by the respective equations

$$\log y = \log v - \int P_1 dx \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$\log z = \log v - \int Q_1 dx \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Equations (4) and (5) obviously become identical when

$$R_1 = S_1, R_2 = S_2, \ldots R_n = S_n \quad . \quad . \quad . \quad . \quad . \quad (8)$$

and this system is necessary and sufficient to determine the relations of the functions $P_1, P_2, \ldots P_n$ and $Q_1, Q_2 \ldots Q_n$, so that (1) and (2) may be connected by (3). The author calculates the criticoidal forms given by the system (8) as far as $R_6 = S_6$, and he obtains results which are all included in the formula

$$\theta_r(P) - \frac{d^{r-1}P_1}{dx^{r-1}} = \theta_r(Q) - \frac{d^{r-1}Q_1}{dw^{r-1}} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

r denoting the degree of the criticoid. In particular he finds

$$\theta_2(P) = P_2 - P_1^2 \quad . \quad . \quad . \quad . \quad (10)$$

$$\theta_3(P) = P_3 - 3P_1P_2 + 2P_1^3 \quad . \quad . \quad . \quad . \quad (11)$$

$$\theta_4(P) = P_4 - 4P_1P_3 - 3P_2^2 + 12P_1^2P_2 - 6P_1^4 \quad . \quad . \quad . \quad . \quad (12)$$

$$\begin{aligned}\theta_5(P) = {} & P_5 - 5P_1P_4 - 10P_2P_3 + 20P_1^2P_3 \\ & - 60P_1^3P_2 + 30P_1P_2^2 + 24P_1^5 \quad . \quad . \quad . \quad . \quad (13)\end{aligned}$$

$$\begin{aligned}\theta_6(P) = {} & P_6 - 6P_1P_5 + 30P_1^2P_4 - 15P_2P_4 \\ & - 120P_1^3P_3 + 120P_1P_2P_3 - 10P_3^2 \\ & + 360P_1^4P_2 + 30P_2^3 - 270P_1^2P^2{}_2 - 120P_1^6 \quad . \quad . \quad . \quad (14)\end{aligned}$$

Of these results the first three, (10), (11), and (12), agree with those already obtained by Sir James Cockle and Mr. Harley, and the last two, (13) and (14), are now published for the first time. The advantage of the method here employed is that the system (8) gives at once $R_n = S_n$, where R is a function of P, and S the same function of Q, whereas by using (1), (2), (3) we are led to Q_n = a certain function of P, and have to obtain the criticoids by means of elimination and other contrivances. A similar remark applies to the case of the change of the independent variable next considered.

Let

$$\left(1, \phi_1(x), \phi_2(x) \ldots \phi_n(x)\right)\left(\frac{dx}{d}, 1\right)^n y = 0 \quad . \quad . \quad . \quad (15)$$

$$\left(1, \psi_1(x), \psi_2(x), \ldots \psi_n(x)\right)\left(\frac{d}{dt}, 1\right)^n y = 0 \quad . \quad . \quad . \quad (16)$$

be two linear differential equations of the nth order, and let x and t be connected by the equation

$$\frac{dx}{P}=\frac{dt}{Q} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

where P and Q are functions of x and t respectively, Sir James Cockle has assumed

$$\frac{1}{P}=\{Q_n(x)\}^n,\ \frac{1}{Q}=\{\psi_n(t)\}^n \quad . \quad . \quad . \quad . \quad (18)$$

Let v be a third independent variable, and assume

$$\Big(1, V_1, V_2, \ldots V_n\Big)\Big(\frac{d}{dv}, 1\Big)^n y=0 \quad . \quad . \quad . \quad . \quad (19)$$

$$\Big(1, W_1, W_2, \ldots W_n\Big)\Big(\frac{d}{dv}, 1\Big)^n y=0 \quad . \quad . \quad . \quad . \quad (20)$$

where (19) is connected with (15), and (20) with (16) by the relations

$$\frac{dx}{dv}=P,\ \frac{dt}{dv}=Q \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

Equations (19) and (20) become identical when

$$V_1=W_1,\ V_2=W_2,\ \ldots\ V_n=W_n \quad . \quad . \quad . \quad . \quad . \quad (22)$$

a system sufficient to connect (15) with (16) by (17).

By this method the criticoids have been calculated for $n=2$, 3, 4 respectively, and the following results obtained:—

$n=2$.

$$\frac{\phi_2^{(1)}(x)+4\phi_1(x)\phi_2(x)}{\{\phi_2(x)\}^{\frac{3}{2}}}=\frac{\psi_2^{(1)}(t)+4\psi_1(t)\psi_2(t)}{\{\psi_2(t)\}^{\frac{3}{2}}} \quad . \quad . \quad . \quad (23)$$

$n=3$

$$\frac{\phi_3^{(1)}(x)+3\phi_1(x)\phi_3(x)}{\{\phi_3(x)\}^{\frac{4}{3}}}=\frac{\psi_3^{(1)}(t)+3\psi_1(t)\psi_3(t)}{\{\psi_3(t)\}^{\frac{4}{3}}} \quad . \quad . \quad (24)$$

and,

$$\frac{\phi_1^{(1)}(x)+2\phi_1(x)^2-3\phi_3(x)}{\{\phi_3(x)\}^{\frac{2}{3}}}=\frac{\psi_1^{(1)}(t)+2\psi_1(t)^2-3\psi_3(t)}{\{\psi_3(t)\}^{\frac{2}{3}}} \quad . \quad . \quad (25)$$

$n=4$

$$\frac{3\phi_4^{(1)}(x)+8\phi_1(x)\phi_4(x)}{\{\phi_4(x)\}^{\frac{5}{4}}}=\frac{3\psi_4^{(1)}(t)+8\psi_1(t)\psi_4(t)}{\{\psi_4(t)\}^{\frac{5}{4}}} \quad . \quad . \quad . \quad (26)$$

$$\frac{22\phi_1(x)^2+12\phi_1^{(1)}(x)-27\phi_2(x)}{\{\phi_4(x)\}^{\frac{1}{2}}}=\frac{22\psi_1(t)^2+12\psi_1^{(1)}(t)-27\psi_2(t)}{\{\psi_4(t)\}^{\frac{1}{2}}} \quad . \quad (27)$$

$$\left.\begin{aligned}&\frac{\phi_1^{(2)}(x)+2\phi_1(x)\phi_1^{(1)}(x)+6\phi_1(x)\phi_2(x)-\frac{20}{9}\phi_1(x)^3-6\phi_3(x)}{\{\phi_4(x)\}^{\frac{3}{4}}}\\&=\frac{\psi_1^{(2)}(t)+2\psi_1(t)\psi_1^{(1)}(t)+6\psi_1(t)\psi_2(t)-\frac{20}{9}\psi_1(t)^3-6\psi_3(t)}{\{\psi_4(t)\}^{\frac{3}{4}}}\end{aligned}\right\} \quad . \quad . \quad . \quad (28)$$

The results (23) to (28) are included in the general formulæ given by Mr. Harley in the paper above cited.

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5. *Complete Integral of the* n-*ic Differential Resolvent. By the* Rev. Robert Harley, *M.A., F.R.S.*

Representing the roots of the n-ic algebraical equation whose coefficients are functions of a single parameter (x) by $y_1, y_2, \ldots y_n$, the complete solution of its differential resolvent is

$$c_1y_1+c_2y_2+\ \ldots\ +c_ny_n,$$

where $c_1, c_2, \ldots c_n$ are independent arbitraries subject only to the condition

$$c_1+c_2+\ \ldots\ +c_n=1.$$

6. *Note on the General Theory of Anharmonics.* By A. BUCHHEIM, *M.A.*

The paper was based on Clifford's paper on the general theory of anharmonics. It contained a general definition of distances, including Clifford's special definitions and remarks on the extension of the notions of involution and harmonic section to systems of more than one dimension.

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7. *Transformations in the Geometry of Circles.* By A. LARMOR, *B.A.*

There is a well-known theory, due chiefly to Hart, Casey, and Darboux, of the contact relations of the eight circles which can be drawn to touch three given circles in a plane—viz., that a certain number of groups of four of these tangent circles touch another circle, thus forming two sets of four circles so related that each circle of either set touches all four of the other.

By treating of plane sections of a sphere instead of circles in a plane, the principle of polarity is made complete, and the method of inversion, which appears somewhat recondite and artificial *in plano,* is there seen in its true projective light. This generalisation also enables us to deduce the descriptive geometry of a quadric considered with reference to its plane sections.

The two chief methods of pure geometry that we may use in extending such results when stated for a spherical surface are:—

(1) If a figure on a spherical surface be connected to any point in space by a cone, this cone will cut the surface again in another figure, which corresponds point for point with the original so that all corresponding angles are equal, and the two figures are therefore similar in their smallest parts though the scale varies from point to point.

This projection is what, in fact, is known in plane geometry as Inversion.

(2) If we draw the great circles of which the points of the given figure are the poles, their envelope will be the reciprocal figure on the sphere. But this envelope clearly consists of two branches, and the reciprocal character of this transformation leads us to the complete statement of the second principle, which is, that the reciprocal of the original diagram, together with its opposite diagram on the sphere, is the envelope of the polar great circles of all its points.

Among other consequences the second principle leads to the extension of Casey's results above referred to—viz. if, instead of the three given circles on the sphere, we consider the complete diagram, consisting of the three given circles and their opposite circles, we are led to groups of four of their tangent circles, each of which touches another circle although their members do not touch the *same three* given circles.

By supposing the three given circles to become points we deduce, as a particular case of this generalisation, the contact relations of the eight circles which can be drawn through the six points of intersection of three given circles on a sphere or in plano. They are of the same nature as those of the eight tangent circles of three given circles—viz. they can be divided into the same number of groups of four, each tangential to another circle.

The contact relations of this group do not seem to have been discussed hitherto.

Casey has also discussed, *analytically,* the contact relations of the thirty-two conics which can be drawn having double contact with a given conic and touching three conics which have double contact with the given conic, showing that they can be divided into a certain number of groups of four, each of which is tangential to another conic having double contact with the given conic.

The two principles mentioned above enable us to deduce this proposition by *pure geometry* from the case of the contact relations of the eight circles touching three given circles on a sphere; and to double the number of groups for which Casey has proved the theorem.

TUESDAY, SEPTEMBER 6.

The following Papers and Report were read :—

1. *On the Magnetic Properties of Gases. By* Professor QUINCKE.

The magnetic pressure on the unit of area in a body is

$$p = \frac{\mathfrak{K}}{8\pi} H_1^2,$$

where H_1 is the strength of the magnetic field. We can compare the difference of the magnetic pressures of two different substances at their common surface with a hydrostatic pressure. This is done for a liquid and a gas by the magnetic manometer—a U tube, with two branches of different diameter, filled with the liquid. The surface of the liquid in the smaller branch is brought into the magnetic field of a powerful electro-magnet; the other branch remains in a field of constant strength. The change h of the height of the liquid with the specific gravity σ is measured, and we have the hydrostatic pressure

$$h\sigma = \frac{\mathfrak{K} - \mathfrak{K}_1}{8\pi} H_1^2$$

where $\mathfrak{K}$ and $\mathfrak{K}_1$ are the diamagnetic constants of the liquid and of atmospheric air.

Dr. Quincke compared in this way, some years ago, different liquids with common air, and has now compared the same liquid (petroleum, alcohol, water) with different gases of different density.

The change of the hydrostatic pressure increases nearly proportionately with the density of the gases. If we assume that the qualities of the liquid are not changed by the absorbed gas, we can find from the difference of the changes of the hydrostatic pressure, divided by the difference of the densities of the gas, the magnetic pressure of the gas for one atmosphere, or the diamagnetic constant $\mathfrak{K}$ in absolute measure for any gas at normal pressure and ordinary temperature.

The gases were compressed by an ordinary compressing pump, with a fly-wheel: the density was measured by an air-manometer, consisting of a horizontal thermometer-tube, closed at one end, containing air and a thread of mercury. The pressure did not exceed 40 atmospheres. The numbers are given in the C.G.S. system :—

	$\mathfrak{K}.\frac{10^{10}}{8\pi g}$	
	Q.	Faraday
Oxygen	0·7355	114·1
Nitric Oxide	(0·257)	
Air	0·1713	100·0
Olefiant Gas	0·0139	97·2
Carbonic Acid	0·0134	96·6
Marsh Gas	0·0057	
Nitrogen	0·0047	96·9
Hydrogen	0·0019	96·5
Vacuum	?	96·6

These results agree with Faraday's relative values (Faraday's 'Exp.,' sec. iii. p. 502).

The diamagnetic constant of a perfect vacuum cannot be found by this method; but only the difference of the diamagnetic constants of a vacuum and the liquid in the magnetic manometer.

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2. *Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements.*—See Reports, p. 206.

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3. *On the Permanence of the B.A. Standards of Resistance. By* R. T. GLAZEBROOK, *F.R.S.*

4. *Final Value of the B.A. Unit of Electrical Resistance as determined by the American Committee.* *By* Professor H. A. Rowland.

5. *On the Specific Resistance of Commercial Iron.* *By* W. H. Preece, *F.R.S.*

The Swedish iron now used for telegraph wire has a specific resistance of 6·034 instead of 6·558 as given in text-books. The specific resistance at 60° F. is

Silver	1·609	Copper	1·642
Pure Iron	9·753	Commercial Iron	9·886

The wire now supplied has a conductivity of 98·44 per cent. of pure iron.

The temperature coefficient is given in the formula

$$R_{t1} = R_t \, (1{\cdot}0048)^{t_1 - t}.$$

6. *On the Influence of a Plane of Transverse Section on the Magnetic Permeability of an Iron Bar.* *By* Professor J. A. Ewing, *B.Sc., F.R.S., and* William Low.

It has been remarked by Professor J. J. Thomson and Mr. H. F. Newall that when an iron bar is cut across, and the cut ends are brought into contact, the magnetic permeability is notably reduced.[1] The attention of the authors was directed to the matter by finding the same phenomenon present itself in experiments on the magnetisation of iron by the 'isthmus' method, and they proceeded to examine the effect by an application of the method Hopkinson has used to measure magnetic permeability.[2] A round bar, nearly half a square centimeter in section, and 13 cms. long, had its ends united by a massive wrought-iron yoke to reduce it to a condition approximating to endlessness; and its magnetisation by various magnetic forces was examined, both when free from stress and when compressed by a load of 226 kilos per sq. cm. It was then cut in the lathe, the halves placed in contact, and the magnetism again examined with and without load. It was next cut into four parts, and finally into eight parts, and magnetised in each case.

Every new plane of section caused a notable loss of permeability. The following are the maximum values of the permeability in each case:—

Solid bar	1220	Bar cut in two	980
Bar cut in four	640	Bar cut in eight	400

Next another bar was tested, first, when solid; next with one cut finished in the lathe; and finally with the cut surfaces faced true by scraping and comparing them with a Whitworth plane. So long as the bar was not compressed, its magnetic permeability was nearly the same, whether the ends were left roughly finished or were faced true. But when load was applied the effect of facing the ends was remarkable: the faced bar then behaved as a solid bar would, while the bar with rough-cut ends still showed a decided defect of permeability as compared with the solid bar.

This made it seem highly probable that the whole effect was due to a film of air between the cut faces. Applying Hopkinson's method to calculate the thickness this film would need to have, in order to account for the observed increase of magnetic resistance, the authors find its thickness is only about $\frac{1}{35}$ of a millimeter when the magnetic force is 10 c.g.s. units, and diminishes to about $\frac{1}{70}$ of a millimeter when the force is 50 c.g.s. units. In the case of the bar cut into four and eight parts, each cut has an effect equivalent to the introduction of a film of this thickness. The authors conclude that in all probability the whole phenomenon is due to the surfaces being separated by these short distances.

[1] *Cambridge Phil. Soc. Proc.*, Feb. 1887.

[2] 'Magnetisation of Iron,' *Phil. Trans.* part ii. 1885.

7. *On the Physical Properties of a nearly Non-Magnetisable (Manganese) Steel. By* Professor W. F. BARRETT.

Early in 1884 Messrs. Hadfield and Co., steel founders of Sheffield, exhibited at the Institute of Mechanical Engineers specimens of steel which they had recently manufactured, containing from 10 to 13 per cent. of manganese. Contrary to the general belief at the time, this steel was found to be extremely tenacious and tough. At the Aberdeen meeting of the British Association Mr. J. T. Bottomley drew attention to the fact that this steel was almost unmagnetisable. His experiments showed that the intensity of magnetisation that could be imparted to it was from 3,000 to 7,700 times less than that which could be given to ordinary steel. The author of the present paper has, through the kindness of Messrs. Hadfield, succeeded in obtaining this steel drawn into wire, but only after reversing the ordinary annealing process; quenching the manganese steel rods in cold water rendered them ductile, and thus lengths of wire were drawn of No. 13 and No. 19 S.W.G. The wire was of two kinds, hard and soft, the latter being as flexible as soft iron wire. This steel contained 13·75 per cent. of manganese, and had a density of 7·81. The hard wire easily scratched steel, not hard tempered. Exposed to the air, it rusts rather more quickly than ordinary steel, but not so quickly as iron. The *modulus of electricity* (Young's modulus) was found, the mean of numerous observations giving $1{,}680 \times 10^6$ grammes per square centimetre for the hard wire, and 1671×10^6 grammes per square centimetre for the soft wire. These numbers are lower than either iron or steel. The *breaking strain* of the No. 19 soft manganese steel wire was found to be 48·8 tons per square inch with 18 per cent. elongation. The hard wire of the same gauge had the enormous breaking strain of 110 tons per square inch, but snapped with scarcely any appreciable elongation. Steel pianoforte wire is the only material with which the author is acquainted that exceeds this tenacity. The *electric resistance* of the wire was found to be 78 microhms per cubic centimetre. This is more than six times the resistance of iron and three times the resistance of German silver. The resistance *temperature coefficient* was found to be 0·136 per cent. for 1° C. for a range of 200° C. This is much lower than iron, which has a temperature coefficient of 0·5 per cent. for 1° C.; but it is higher than German silver, which gave only 0·04 per cent. for 1° C. Hence for resistance coils for electric lighting manganese steel wire may be useful. The *magnetic susceptibility* of manganese steel was also carefully examined and found to be extremely low: in similar powerful magnetic fields, if iron be taken as 1,000, manganese steel is less than 3. The enormous magnetic change wrought in this material by the alloy of 12 to 13 per cent. of manganese is very remarkable, and indicates a valuable application of this material for the bed plates of dynamos and for iron-plated vessels. An iron-clad built of manganese steel would not only be of great strength, but would have practically no deviation of the compass.

In conclusion the author pointed out that manganese steel wire does not exhibit the anomalous expansion on cooling and recalescence which is found in ordinary iron and steel wire. This affords new evidence of the connection between these peculiar molecular phenomena and the magnetic state of the body.

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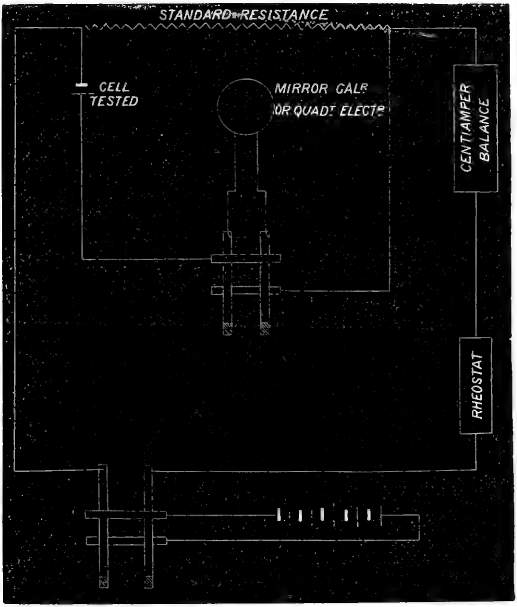
8. *On the Application of the Centi-ampere or the Deci-ampere Balance for the Measurement of the E.M.F. of a Single Cell. By* Professor Sir WILLIAM THOMSON, *F.R.S.*

For the purpose of measuring the E. M. F. of a single cell the centi-ampere or the deci-ampere balance is put in circuit with a battery of a sufficient number of cells, a rheostat, and a standard resistance, in the manner shown in the diagram. The current measured by the balance is then varied by means of the rheostat until the difference of potential between the ends of the standard resistance is exactly equal to the potential of the cell. This equality is tested by placing the cell in series with a mirror galvanometer or a quadrant electrometer in a derived circuit,

the ends of which are connected with the ends of the standard resistance, and observing whether any deflection is obtained by closing this circuit.



Suppose, for example, the standard resistance to be 10 ohms, and the current as indicated by the balance, 0·108 amperes; when no deflection is obtained on the mirror galvanometer by closing its circuit, the potential of the cell is 10 × ·108, or 1·08 volts. Proper precautions must of course be taken to eliminate thermo-electric or other disturbances in the circuit.

The quadrant electrometer may be used with advantage in the derived circuit when it is important that no current should flow through the cell, but the mirror galvanometer has the advantage of much greater sensibility.

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9. *On Induction between Wires and Wires.* *By* W. H. Preece, *F.R.S.*

A continuation of a subject brought before the Association last year, when it was shown that electro-magnetic disturbances extended to distances much greater than was imagined, and that effects were observed across many miles of country. Experiments were made on the banks of the Severn and Mersey, on the Portcawl Sands of South Wales, in the fields in the neighbourhood of Cardiff, on the roads and railways in Oxfordshire, Worcestershire, and Shropshire, in the air and under water, in the corridor of the General Post Office in London, and the law was formulated that the distance depended directly on the strength of the currents inducing the disturbance, and on the length of the wires opposed to each other, and inversely on the square of the distance separating them, and on the electrical resistance of the disturbed wire.

The influence of one mile of wire carrying one ampere of current can apparently extend to a distance of 1·9 miles. The law is given by the following formula:—

$$C_2 = M \frac{c_1 l}{d^2 r_2},$$

where c_1 is the primary current, c_2 the secondary, l the length of the wires opposed to each other, d the distance separating them, r_2 the resistance of the secondary circuit. When these quantities are represented in C. G. S. units M equals ·005.

The current induced by one mile of one ampere at one mile distant is $1{\cdot}3 \times 10^{-13}$ amperes. A current is still perceptible at 1·9 miles distant; hence we can calculate that a bell telephone requires six ten-thousand millionths of a milliampere, or in figures ·0000000006 milliampere to be audible.

One curious result of these inquiries is that the disturbances are transmitted equally well through water and the earth as through air, and hence our cables are disturbed as well as our land wires. Communication with coalpits is possible, though nothing but the earth intervenes.

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10. *On the Coefficient of Self-Induction in Telegraph Wires.* *By* W. H. Preece, *F.R.S.*

The value of the coefficient L is given in terms of 10^{-9} centimetres per mile. It is very easily obtained on automatic circuits worked on the duplex system at high speed. It is so small in copper that it may be neglected.

The value of L in iron wire was found to be

By the duplex method ... ·00498
By direct measurement ... ·0051
The mean result being ... ·00504

Hence L for iron wire, such as is used for telegraph circuits, may be taken as

$$\cdot 005 \times 10^{-9} \text{ centimetres per mile,}$$

while that for copper is less than

$$\cdot 00001 \times 10^{-9} \text{centimetres per mile.}$$

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11. *On the General Theory of Dynamo Machines.*[1] *By* Edward Hopkinson, *D.Sc.*

A dynamo consists essentially of two closed circuits or 'tubes,' in both of which there is a displacement of the nature of a flux dependent upon the relative motion of the two circuits. We may call one of these the 'magnetic circuit,' and the other the 'electric circuit.' Either or both of these may be in motion; but as we are concerned only with the relative motion of the two, we may for convenience (as, in fact, is usually the case) regard the magnetic circuit as fixed, or displaced only by the reaction of the electric circuit upon it, and consider the latter only as moving under external forces, whether electrical or mechanical. The flux along the magnetic circuit is called the 'magnetic induction,' which is a vector or directed quantity, requiring for its definition reference to co-ordinate axes. It is subject to the fundamental condition known as the 'solenoidal condition,' or 'equation of continuity.' The flux along the second circuit is called the 'electric current,' and is also a vector quantity, subject to the solenoidal condition. Neither circuit is necessarily bounded by the limits of the machine, and both may be and generally are subdivided. Both these fluxes are produced by corresponding forces, called respectively 'magnetic force' and 'electromotive force,' which likewise are vector quantities, but are defined by reference to a line instead of by an area, as is the case with the fluxes. (Maxwell, 'Treatise on Electricity and Magnetism,' vol. i. p. 10.) We now require to know the relation between each force and its corresponding flux. Let us first inquire into the relation between the magnetic induction (B) and the magnetic force (H). Such a relation may be expressed by the general equation

$$B = f^{-1}(H) \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

The form of the function depends upon the medium in which the tube is drawn,

[1] For paper in full, see *The Electrician*, vol. xix. Sept. 9, 1887.

and also upon the physical conditions of the medium. For air and all other gases, and generally for all substances classed as 'non-magnetic,' it is a linear function possessing one coefficient or constant only. For such substances the equation may be written

$$B = \mu H \quad . \quad . \quad . \quad . \quad . \quad . \quad (\beta)$$

Since the numerical definition of H is at our disposal, we may so define H that μ is unity for all the substances above referred to.

For iron, and generally for all magnetic substances, H is not a linear function of B, and its expression will involve several constants depending upon the medium, and such physical conditions as temperature and strain, and its previous history. The determination of the form of the function for iron in particular has been the subject of a great number of experiments, but no general expression has yet been discovered, and it has usually been found most convenient to record the experimental results in the form of a curve referred to rectangular axes, in which the ordinates represent magnetic induction and the abscissæ magnetic force. Such curves have been fully investigated for iron of various composition, and under varying physical conditions, among others particularly by G. Wiedemann ('Die Lehre vom Galvanismus,' vol. ii. p. 340, *et seq.*), Rowland ('Phil. Mag.' Aug. 1873), Carl Barus and Vincent Strouhal ('Bulletin of the United States Geological Survey,' No. 14, 1885), J. Hopkinson ('Phil. Trans. R.S.' pt. ii. 1885), J. A. Ewing ('Phil. Trans. R.S.' pt. ii. 1885, and pt. ii. 1886, and 'Proc. R.S.' vol. xlii. p. 200, 1887). For convenience we may still express the curve by the equation (β), μ is then the tangent of the angle which the tangent to the curve makes with the axis of x.

Secondly, we require to know the relation between the E.M.F. and current. This is well known to be expressed by a linear relation, known as Ohm's law, involving one constant coefficient only.

Having now defined the relation between the fluxes and their corresponding forces, it remains to consider the relation between the fluxes themselves, dependent upon the relative motion of their circuits. This may be expressed in various ways, all of which are the expressions of Faraday's well-known law: *e.g.*, the line integral of the E.M.F. round the electric circuit is the rate of decrease of the surface integral of magnetic induction through any area bounded by the circuit.

Excluding for the moment the consideration of magneto machines with permanent magnets, and of machines in which iron plays no part whatever, we may more particularly consider that class of dynamos in which the magnetic field is produced by the use of iron excited by a current; and we then require to know the relation between the current and the induction in the magnetic field produced by the current. Faraday showed that the magnetic field in the neighbourhood of an electric current is the same as that of a magnetic shell bounded by the circuit of the current, and has therefore a similar magnetic potential. This is expressed by saying, that the line integral of magnetic force round any closed curve is zero, provided the closed curve does not surround the electric current; and if the current passes through the closed curve, then the line integral is proportional to the number of times it passes through, and is equal to $4\pi nc$, where c is the current and n the number of times it passes through the closed curve.

We have now the materials for a complete investigation of a dynamo of any given configuration and constructed of iron, whose magnetic qualities are known. It is required to determine the E.M.F. and current in the electric circuit, as its configuration relative to the magnetic circuit is changed by the application of external forces, and as the magnetic forces in the magnetic circuit are changed either by external electro-magnetic forces, or electro-magnetic forces derived from the current circulating in the electric circuit. The magnetic circuit consists in general of four parts: (i.) The magnet limb, which is surrounded by coils of wire, through which the exciting current is passed. (ii.) The field pieces, or the extended polar extensions of the magnet limb, embracing the armature. (iii.) The air space being the necessary interval between the iron of the pole pieces and the iron of the armature, or in cases where the armature contains no iron, the interval between the

opposed pole pieces. (iv.) The armature, or that part of the machine carrying that portion of the electric circuit which is subject to displacement under external forces.

The magnetic circuit is thus subject to magnetic forces due to the current in the armature and the current round the magnet limb. We must therefore, in the general case, take these as the two independent variables, which we may denote by C and c. Now, it may be assumed with sufficient accuracy that in the magnet limb the boundaries of the tube of magnetic induction are coincident with the boundaries of the iron, and the cross section of the tube the same as the cross section of the iron. Outside the limb a portion of the lines of force will complete a magnetic circuit through external space, and will not enter the pole pieces. The extent of this leakage or induction, from which no useful effect is obtained, depends upon the configuration of the machine and the degree of saturation of the iron, and could be calculated therefrom; but as it can be experimentally determined for any machine with great ease, it is unnecessary to consider it further, and we may regard the total induction in the magnet limb as greater than the induction in the pole pieces in a constant ratio, which we will denote by ν_1. It is usual to construct the pole pieces of large section compared with the magnet limb, and hence the section of the pole pieces may again be taken as the section of the tube of induction; but as the lines of force leave the pole pieces to cross the air space, we cannot ascribe any boundary to the tube, but in every machine a portion only can pass through the armature, and part must pass from one pole piece to the other by lines external to the armature. Moreover, the relation between the two parts will not be a constant one, unless the magnetic forces in the armature are constant, which can never be the case. It is therefore necessary to consider the tube of induction, which crosses the air space and enters the armature, as a variable portion of the whole tube, the variation depending upon the magnetic forces in the armature. We may denote the ratio of the induction through the pole pieces to the induction through the armature by ν_2. Let A_1 be the cross section of the magnet limb, l_1 its length; A_2 the cross section of the pole pieces, l_2 the mean length of the tube therein; A_3 the cross section of the air space, comprising all the space through which the lines entering the armature pass, l_3 its length; A_4 the cross section of the iron of the armature (if it contains iron), and l_4 the mean length of the tube of force therein. Then the line integral of magnetic force taken round the circuit is:—

$$\frac{1}{\mu_1} l_1 \frac{\nu_1 \nu_2 \mathrm{I}}{A_1} + \frac{1}{\mu_2} l_2 \frac{\nu_2 \mathrm{I}}{A_2} + \left(\frac{1}{\mu_3}\frac{l_3}{A_3} + \frac{1}{\mu_4}\frac{l_4}{A_4}\right)\mathrm{I}$$

the μ's being the coefficients of magnetic induction for the several portions of the circuit. For air the coefficient is unity, hence $\mu_3 = 1$. I is the total induction in the armature, which is assumed to be uniformly distributed over the tube. Now the magnetic circuit is cut by the current in the magnet coils and the current in the armature. Let n_1 be the number of times it is cut by the former, n_2 by the latter. Then

$$\frac{1}{\mu_1} l_1 \frac{\nu_1 \nu_2 \mathrm{I}}{A_1} + \frac{1}{\mu_2} l_2 \frac{\nu_2 \mathrm{I}}{A_2} + \left(\frac{l_3}{A_3} + \frac{1}{\mu_4}\frac{l_4}{A_4}\right)\mathrm{I} = 4\pi(n_1 c + n_2 \mathrm{C}).$$

It must be noted that the direction in which the circuit is cut by c and C is in both cases taken to be positive. Referring to three rectangular axes and measuring the induction along the axis of z, the current round the magnets along the axis of x, and that in the armature along the axis of y, the above equation may be written

$$l_1 f_1\left(\frac{\nu_1 \nu_2 z}{A_1}\right) + l_2 f_2\left(\frac{\nu_2 z}{A_2}\right) + l_3 \frac{z}{A_3} + l_4 f_4\left(\frac{z}{A_4}\right) = 4\pi(n_1 x + n_2 y).$$

This represents a surface the ordinate at any point of which is the induction through the armature. Such a surface was first described by Dr. John Hopkinson ('Lecture before the Inst. of C.E.,' April, 1883), and is called the 'characteristic surface.'

Having obtained a general expression for the induction in the armature, the

electromotive force in the electric circuit, when displaced, can be deduced by Faraday's law.

Consider now the application to alternate current machines. Such machines are usually multipolar. In machines of the disc type the number of poles is even, and the armature is divided into sections corresponding to the number of poles, and revolves uniformly between them. The tube through any one pair of opposed poles and back through another need only be considered, and the total effect of the machine obtained therefrom by summation. Suppose the iron of both magnets and armature so arranged that no currents are induced therein. There is then only one electric circuit to deal with. The whole current in one section of the armature cuts the magnetic tube passing through the section, as many times as there are convolutions. Let m be the number of convolutions. The current x round the magnets is usually derived from independent sources, and maintained constant. For each such constant value the characteristic surface becomes a curve giving the relation between the induction through the armature and the current in it. The areas A_1, A_2, and A_4, and the lengths l_1, l_2, l_3, and l_4 are constant, but the area A_3 is a periodic function of the time, and can be expressed by a series of cosines, the coefficients of the series being determined by Fourier's theorem from the dimensions of the machine. If the equation of the characteristic be differentiated with regard to the time, we shall obtain an equation of the form

$$A\,\dot{y} + B\,y = \text{periodic function of } t,$$

when B is constant and A is a periodic function of t, but usually assumed to be constant, and called the 'self induction' of the machine.

In general no current continuous in direction can be obtained by continuous rotation of any part of the electric circuit, unless arrangement is made for reversing the current at a certain stage of each revolution. To diminish the oscillation of the current the electric circuit is divided into a number of sections, arranged symmetrically on the armature, the current in one or two of which only is reversed at a time. If the number of sections be even and equal to $2m$, one half will be in series, and one half the total current will pass through each half, except at the instant of commutation. At such time two sections are short circuited, and form complete circuits in which the current will be determined by the induction through them at the time; and the number of sections in series will be $\overline{m-1}$. If the number of sections be odd and equal to $\overline{2m+1}$, one section only will be commuted at a time, and at that instant there will be m sections in series. At other times there will be $\overline{m+1}$ sections in series on one side and m on the other, and consequently there will be a superposed current flowing through the armature only, due to the inequality in the number of sections in series in the two halves. In one revolution of the armature the tube of induction through it will be cut four times by each section, and if the plane of commutation is symmetrical with regard to the tube of induction the current in one half the sections will cut it in the opposite direction to that in the other half. In this case, $n_2 = o$. But any displacement of the plane of commutation from the symmetrical position will cause the current in a greater number of sections to cut the tube in one direction than in the other. Let λ be the angular advance of the plane of commutation, and m the number of sections in the armature; then $n_2 = \frac{\lambda m}{\pi}$. The value of λ may be fixed for any given machine, or varied at pleasure, or may be determined to avoid sparking at the time of commutation of a section. The general discussion of the value of λ to effect this has not yet been attempted. For the present λ must be regarded as independent. The general equation of the characteristic surface becomes for a continuous current machine

$$l_1 f_1\left(\frac{\nu_1 \nu_2 z}{A_1}\right) + l_2 f_2\left(\frac{\nu_2 z}{A_2}\right) + l_3 \frac{z}{A_3} + l_4 f_4\left(\frac{z}{A_4}\right) = 4\pi n_1 x - 4\lambda m y,$$

λ being reckoned positive when the displacement is in the direction o rotation.

If no current passes through the armature, $y = o$ and ν_2 may be taken as constant

and determined by experiment. The equation may then be written

$$l_1 f_1\left(\frac{\nu_1\nu_2 z}{A_1}\right) + l_2 f_2\left(\frac{\nu_2 z}{A_2}\right) + l_3 \frac{z}{A_3} + l_4 f_4\left(\frac{z}{A_4}\right) = 4\pi n_1 x,$$

which is the equation to the characteristic curve of a shunt-wound or separately excited machine. Having determined the characteristic when $y = o$ the characteristic surface can be determined therefrom by considering the form of ν_2. (See J. and E. Hopkinson, 'Trans. R. S.' pt. i. 1886, p. 334.)

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12. *On the Production of a Constant Current with Varying Electromotive Force from a Dynamo. By* A. P. TROTTER, *B.A.*

The well-known methods are by (1) rocking the brushes; (2) compound winding; (3) reducing the strength of the field.

The first method cannot be adopted with a modern ring or drum armature in a strong field, though it is used with some success in the Thomson-Houston and Hochhausen systems. Compound winding can only produce a very rough approximation to a constant current; and, lastly, the strength of the field cannot be reduced far without working on the nearly straight part of the saturation-curve, when the electromotive force becomes unstable.

Mr. Ravenshaw, the senior electrician of Messrs. Goolden and Trotter, proposed to keep the field saturated, but to weaken its useful effect by a movable yoke or keeper, which, by offering a low magnetic resistance, would divert the magnetism from the armature without materially altering the saturation of the magnets. The writer suggested that, instead of moving this keeper, its effect could be annulled by winding on it a coil through which a comparatively feeble current might circulate.

The general method which, with certain precautions, has been put to practical use with complete success, is, therefore, as follows:

To a dynamo with a single horseshoe field another magnetic circuit is applied, such as a similar horseshoe, which under ordinary circumstances would offer a so much smaller magnetic resistance than the armature and its air-space, that nearly all the lines of force would be diverted through it.

This is the condition of minimum electromotive force.

This second magnetic circuit is provided with coils like those of the main magnet, and by the passage of a current through these coils the diversion of the magnetism of the main magnets may be obstructed, until, with a certain strength of current, no lines of force will pass through the second magnetic circuit, and the electromotive force of the armature will be produced solely by the whole useful magnetism of the main magnet. As, however, the second magnetic circuit is similar to the main magnet, it may be used in the same way, and by further increase of the current through its coils may assist the main magnet, until the effect of the two is combined, thus doubling the output of the machine as first described.

This is the condition of maximum electromotive force.

In a shunt machine the current through the coils of the second magnet may be controlled by the addition of a resistance in series with it. In a series machine the current may be controlled by a resistance arranged as a shunt on the coils, or by dividing the coils into sections. These resistances, whether in series with shunt coils or as shunts on series coils, may be controlled by hand or by automatic regulators.

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13. *Description of an Induction Coil. By* GEORGE HIGGS.

This induction coil was designed and constructed specially for the purposes of spectrum analysis; the dimensions of the various parts are given as follows:—

The core, which is 14 inches long by $1\frac{1}{4}$ inch in diameter, is composed of very soft iron wire, No. 20 B.W.G., but although selected with considerable care the residual magnetism is very perceptible.

The primary wire is of No. 12 copper, double covered with cotton wound in three layers, and about 40 yards in length, the whole accurately fitting inside an

ebonite tube $\frac{1}{4}$ inch in thickness. A pole-piece is screwed on to each end of the core.

The secondary is wound in 52 sections, having an average of about 1,200 turns of wire to each section, taking in all $14\frac{3}{4}$ miles of double silk covered copper wire, Nos. 35 and 36 B.W.G. The maximum outer diameter of secondary is $5\frac{1}{2}$ inches in the middle, and the minimum at ends is $3\frac{1}{4}$ inches, the inner diameter $2\frac{5}{8}$ at the middle and $2\frac{7}{8}$ at each end; the length of secondary body is 11 inches, the terminals $10\frac{1}{16}$ inches asunder.

There are three condensers of 40, 30, and 20 sheets of tinfoil respectively, the sheets being $10 \times 7\frac{1}{2}$.

The vibrating spring of contact-breaker is cut in two near the foot, and a tongue of hardened and tempered steel let in and securely riveted.

This principle is found to be of great use in photography, the spectra of metals, and gases, as the vibrations are accelerated thereby.

The main feature, however, resides in the new method of insulation between the sections, the thickness of insulation being made to vary as the differences of potential between the parts of any two adjoining sections.

The coil is capable of giving sparks between nine and ten inches in length, with one quart bichromate cell. With this instrument and the photographic apparatus described on a former occasion, the author proposes to photograph and map the spectra of chemical elements, the solar lines, and those of the spectrum of iron to be used as reference lines. The *w.l.'s* for a considerable portion may be obtained from Professor Rowland's normal map by simple inspection; but throughout the *w.l.* according to Angström will be also used. The sheets will illustrate the plan proposed.

WEDNESDAY, SEPTEMBER 7.

The following Reports and Papers were read:—

1. *Third Report of the Committee on Standards of Light.*—See Reports, p. 47.

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2. *On a Standard Lamp.* *By* A. VERNON HARCOURT, *M.A., F.R.S.*

At one of the meetings of this Section last year a lamp devised by the author for producing a constant amount of light was shown and described by Mr. W. S. Rawson. The lamp now exhibited served the same purpose, but was simpler in principle, more easily adjusted, and less affected by draughts. It consisted of a glass reservoir with tubulure and stopper, of the form and size of a large spirit lamp, mounted on a metal stand provided with levelling screws. The wick could be turned up and down in the usual manner within a long tube attached to the body of the lamp. Round this tube is a wider tube 100×25 mm.; and the two being joined together above and below by flat plates constitute the burner of the lamp. When the burner becomes warm by conduction of heat from the flame the pentane which rises in the wick volatilises, and the vapour burns at a considerable distance above the point to which the wick is turned down. Thus the size or texture or quality of the wick does not affect the flame.

Around the burner and the lower part of the flame was another cylinder open at both ends and contracted above the burner to a tube 20 mm. in diameter and in length. A similar tube formed the lower part of an upper chimney which was enlarged above to a diameter of 25 mm. The upper part of the flame was concealed by this chimney excepting where a narrow slot 10×3 mm. on each side showed the tip of the flame, and enabled its height to be regulated. Through the interval between the two chimneys the flame shines, and the light which it gives is the same whenever the tip of the flame is visible opposite the slot, whether towards the lower or the upper end.

The two chimneys were attached together by two curved metal bands sufficiently removed from the flame on either side not to affect it. The attachment of these bands to the lower chimney was adjustable, so that the opening through which the central parts of the flame were seen might be made larger or smaller. By means of small cylindrical blocks, whose thickness was accurately gauged, the width of the opening might be set either to that at which the light emitted was one candle, or, if a greater or smaller light was desired, a candle and a half, or half a candle. The width of the connecting bands was half that of the tube which surrounds the flame. When these bands were placed in a plane perpendicular to the bar of a photometer, a point midway between their edges and at half the height of the flame might be taken very approximately as that from which the light radiated.

The liquid with which the lamp is fed is pentane, obtained in a manner already described from American petroleum.

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3. *Second Report of the Committee for inviting designs for a good Differential Gravity Meter.*—See Reports, p. 41.

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4. *Report of the Committee for considering the desirability of combined action for the purpose of Translation of Foreign Memoirs.*—See Reports, p. 41.

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5. *Contributions to Marine Meteorology from the Scottish Marine Station.*[1] *By* HUGH ROBERT MILL, *D.Sc., F.R.S.E., F.C.S.*

Observations have been carried on during three and a half years on the temperature and salinity of the sea and its inlets at various points of the coast of Scotland and on various inland lakes. The general result has been to show a marked difference between the seasonal changes of temperature in sea-water and in the water of inland lakes of equal depth. There is a distinct difference also in the conditions of the water on the east and on the west coasts of Scotland.

In the deep rock-basins and submerged valleys of the west coast a very singular vertical distribution of temperature has been detected and its seasonal changes watched. The Clyde sea-area was selected for particular study, as presenting a variety of natural conditions readily accessible at all seasons. Results obtained there show for (1) the *Irish Channel* a uniform temperature from surface to bottom, changing regularly with the season, but higher all the year round than the mean of the enclosed regions; (2) the *deep open basins* in free tidal communication with the ocean resemble the Channel at all depths beneath thirty fathoms. The surface water changes more rapidly in temperature than that below, and hence is warmer in summer and colder in winter than the mass; (3) the *deep enclosed basins*, almost cut off from the tide and shut in by steep mountain walls, show the greatest range of annual temperature, and the most complicated vertical distribution. The surface water is quite fresh after heavy rains and freezes in winter. The annual range may be 35° or 40° F., while at the bottom (seventy fathoms) 5° is the greatest range observed, and the maximum temperature there occurs in early spring, when the surface water is at its minimum; the minimum at the bottom occurs in the beginning of autumn, when the surface attains a maximum.

Superposed layers of water at various temperatures have been frequently observed, and the curves of vertical change show abrupt transitions, often amounting to several degrees in a single foot, at considerable depths beneath the surface. The subject is being investigated from the side of the specific heat and conductivity of sea-water of various salinities.

[1] Published *in extenso* in the *Scottish Meteorological Society's Journal*, 3rd ser. vol. viii.

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6. *The Direction of the Upper Currents over the Equator in connection with the Krakatoa Smoke-stream.* *By* Professor E. DOUGLAS ARCHIBALD.

The object of this communication is to show that the results of an examination of the data regarding the stream of volcanic dust, &c., which issued from Krakatoa on August 26 and 27, 1883, are not at variance with what can be legitimately deduced from the general theory of atmospheric circulation, as well as with what is at present known from observation regarding the gradients and velocity of the air in the neighbourhood of the equator.

The results of the Krakatoa inquiry necessitate the existence of a constant current over, and in the neighbourhood of, the equator, at a height of from 80,000 to 120,000 feet, and of a velocity of from 75 to 80 miles an hour.

1. In order to test the probability of this hypothesis reference is made to the general theory and to the equation for the poleward gradient

$$\Gamma_N = 2V_E\omega \sin\phi + \frac{V_E^2 \sin\phi}{R} + \frac{dV_N}{td} + F_N$$

as given in Sprung's 'Lehrbuch.'

Where Γ_N = gradient towards the north.
ω = earth's angular velocity of rotation.
V_E = velocity towards the east.
V_N = velocity towards the north.
ϕ = latitude.
F_n = friction term.
R = radius of the circle of latitude.
t = time.

Now in the neighbourhood of the equator the term $2V_E\omega \sin\phi$ vanishes, and at a great height F_N becomes very small. Also $\frac{dV_N}{dt}$, representing a term depending on rapid changes of velocity, becomes very small. The air at the higher levels near the equator may thus move from W. to E., or E. to W., with considerable velocity without any sensible gradient. The possibility of its moving rapidly in a meridional direction is omitted, since, the equator being an axis of symmetry with respect to the adjacent regions, there is no reason why the air should move across it towards one pole more than the other.

2. It is next shown that if the air is initially moving at the higher levels from E. to W. there is no theoretical cause which would turn it from this course in the neighbourhood of the equator, since the radius of the inertia curve in which the air over a rotating sphere tends to move, viz. $\frac{V}{2\omega \sin\phi}$ becomes very large in this region, and ultimately ∞ at the equator itself.

The deviating influence of inertia relative to the earth's surface would only begin to make itself felt at some distance from the equator, and the air moving from E. to W. would gradually curve round through S.E. to S., and finally to S.W., the direction which the upper current, as exhibited by the motions of the upper clouds, is known to have at the borders of the trade zone.

3 The *general* tendency of the lower air in the region of the trades to move from some easterly to some westerly points and rise in the neighbourhood of the equator would favour the upper air moving in the same direction, since the former in rising would communicate its westward component to the latter.

4. The curves of barometric pressure calculated by Professor Sprung from data furnished by Professor Ferrel for a mean longitude at

(*a*) Sea level
(*b*) 6,558 feet
(*c*) 13,116 feet

show that the gradient over the neighbourhood of the equator and for 20° on either side is very small, and that thus the air would not have a tendency to stream towards the poles and so acquire a W. to E. motion until it had arrived at some distance from the equator.

5. The observations of Mr. Abercromby on the motions of the upper clouds over the equatorial zone, so far as they go, favour the notion of an E. to W. motion of the upper air, and would seem to show that this is unaffected by local influences such as monsoons.

6. The velocity of the current, though greater than that of any known constant winds at the earth's surface, is by no means out of proportion to them if we may assume the general law of increase of velocity with the height as deduced from Dr. Vettin's, and other cloud and wind observations to hold good to a height of 120,000 feet.

For if we reduce the velocity of 80 miles an hour at 120,000 feet down to 1,000 feet by the formula [1]

$$\frac{V}{v} = \sqrt[4]{\frac{H}{h}}$$

we shall find it $= 24{\cdot}17$ miles per hour; and if we reduce this again to 100 feet by the formula

$$\frac{V}{v} = \sqrt[3]{\frac{H}{h}}$$

which holds better than the former for heights below 1,000 feet, we shall get 11·2 miles per hour for the velocity near the surface, which would normally correspond with a velocity of 80 miles an hour at an elevation of 120,000 feet above it.

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7. *On a Comparison-magnetometer.* *By* W. W. Haldane Gee, *B.Sc.*

This is a simple apparatus of great convenience for rapidly comparing the moments of magnets by opposing them on opposite sides of a suspended magnet. The magnets under comparison are placed on two wooden arms having millimètre scales that are fixed at right angles to a box containing the suspended magnet. For most experiments the formula $M/M' = D^3/D'^3$, where M, M′ are the moments of the magnets, and D, D′ the distances of their centres from the suspended magnet, gives sufficient accuracy, providing that the magnets are not too long or too weak. The method becomes one of differences by taking double observations, and the accuracy may be further improved by taking account of the lengths of the magnets in the manner described in the paper. The apparatus is also adapted for electromagnetic and galvanometric measurements.[2]

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8. *On Expansion with Rise of Temperature in Wires under Elongating Stress.* *By* J. T. Bottomley, *M.A., F.R.S.E., F.C.S.*

This paper gives a preliminary account of experiments undertaken for the purpose of determining the longitudinal expansion with rise of temperature in wires subjected to different elongating stresses. The investigation has been undertaken partly in connection with the secular experiments on elasticity of wires initiated by a committee of the British Association in 1876.

Two copper wires hung side by side in a tube of tin plate about 6 metres long are alternately heated by steam and allowed to cool. One of these wires carries one-tenth of its breaking-load; the other, half of its breaking-load.

After a preliminary process of hardening of the wires, found to be necessary and described in the paper, comparisons were made as to the expansibility with rise of temperature of the heavily loaded and lightly loaded wires.

The investigation is far from complete, but there seems no doubt that there is a measurable difference between the two expansibilities, that of the heavily loaded wire being the greater.

The experimenting came to an end at the beginning of May, when the supply of steam from the heating apparatus in the Glasgow University Laboratory ceased to be available; but the wires are left hanging, carefully protected, and the investigation will be resumed in October next.

[1] Cf. *Report of British Association* for 1884, p. 639.
[2] See *Electrical Review*, October 7, 1887, p. 370.

9. *On the Electrolysis of a Solution of Ammonic Sulphate.* *By* Professor McLeod, *F.R.S.*

10. *Compensation of Electrical Measuring Instruments for Temperature-Errors.* *By* J. Swinburne.

11. *A Musical Slide Rule.* *By* J. Swinburne.

This is an instrument in which the distances between the marks are proportional to the intervals—that is to say, the distances are proportional to the logarithms of the vibration frequencies. This arrangement appeals to the eye and gives clear ideas of the musical scale. In the accompanying scale the first fixed scale is the ordinary equal temperament, the octave being divided into twelve equal parts. The other fixed scale is the natural, and by means of the cursor the discrepancies can be seen at once. On one side of the moving slide are two scales, one being the natural and the other being the octave, divided into 53 equal parts, commonly known as Bosanquet's cycle. By shifting the slide the various intervals can be added or subtracted. Thus, by putting C against F it is seen that D comes opposite G, showing that the interval C–D is equal to F–G. The model being graduated by hand is not correct throughout, but is sufficiently accurate to show the working of the instrument. The cursor shows how nearly the cycle of 53 corresponds with the natural scale. On the other side of the movable slide are scales of vibrations and logarithms. To find the vibration frequency of, say, E French pitch, equal temperament, the line 5 is set opposite the mark on the equal temperament scale, and the number of vibrations read off. For the natural scale the other mark must be taken, as the scales are drawn so that the C's correspond; the A's, therefore, do not come opposite. The logarithm scale is used for finding the logarithm of any interval.

It is suggested that such an instrument as this would give musical students a much clearer idea of the nature of intervals and of the problems of temperament.

12. *On a certain Method in the Theory of Functional Equations.* *By* Professor Ernst Schröder.

In order to prove that a functional equation does *not* follow from another given one, it is indispensable to discover such a function as will satisfy the latter equation without, however, satisfying the former.

If, for brevity's sake, a function $f(x, y)$ of two variables—supposed to be determinatively invertible—is here denoted by xy, its inverse functions accordingly being represented by $\frac{y}{x}$ and $x : y$, then, for instance, from the equation

$$C_0)\ ab = a : b$$

evidently will follow:

$$C_{00})\ (ab)c = (a : b) : c.$$

The impossibility, however, of deducing C_0 from C_{00} may be demonstrated (and it cannot be done in any simpler way) by means of the following table:—

1 = 3,69,187245	4 = 6,93,421578	7 = 9,36,754812
2 = 1,47,298356	5 = 4,71,532689	8 = 7,14,865923
3 = 2,58,379164	6 = 5,82,613497	9 = 8,25,946731

which in fact defines, within a system of nine numbers only, a function xy, so as throughout to fulfil the equation C_{00}, but not C_0.

The meaning of the table is easily explained through the statement that its first line is only an abbreviation for $1 = 33 = 69 = 96 = 18 = 87 = 72 = 24 = 45 = 51$, where 33 stands for $f(3, 3)$, and so on.

13. *On the Nomenclature of Elementary Dynamics. By* JOHN WALMSLEY, *B.A.*

The exposition of the subject is in need of a suitable nomenclature and is unsettled in phraseology.

First felt strongly in regard to 'acceleration,' which is used to denote increase of rate of velocity, and also rate of the same increase. Restricting it to the latter, 'addend' may be used for addition made to velocity, and the same term is useful elsewhere. This removes only part of the risk of confusion.

Matter is the medium of motion, so far as we consider it. The mass of matter may be called the *extension* of motion, while velocity is its *intensity*. These are its two real *dimensions* (*not* derived dimensions), whence momentum is *mv*. Momentum is used confusedly, its meaning of *quantity* of motion being overlooked. 'To charge' (borrowed from electricity) would be a useful term in speaking of infusing motion into mass.

Unit of mass called 'mass-pound' might be called *libra* with advantage, so as to avoid rivalry with 'weight-pound.' The symbol *l.* would be distinct from *lb.*

Force is defined as '*cause*' of motion, which can only mean flow of momentum. This may be called 'impulsion,' uniformly with 'impulse,' which Maxwell uses for the result of it. Then *rate* of impulsion is force according to stricter definition we have to come to later on. The 'cause'-definition evidently very bad preparation for the final one, and not now needed.

'Force is said to do work when it moves its point of application.' This definition absurd in both clauses. Force is a 'rate' of charging mass with momentum, and is only one of two main elements of work, the other being linear space. Force cannot, strange as it may seem, move anything, but energy may. These and other points regarding new parts of dynamics should be kept out of influence of old habits of the subject.

Difficulties glanced at would be relieved by the adoption of unit-names. Numerous proposals on the subject show the want is felt. But some think formulæ in L, M, T would suffice. These would show relationships between units, and would assist in many ways.

We may get the advantage of formulæ combined with ease and *brevity* of articulation with a little extra trouble at the outset.

Represent mass-unit by *l.* (for libra), length-unit by *f or o*, but not both at once, time-unit by *s or e*, the representation of the last two being thus dual. Formula-names follow for the derived units of ordinary elementary dynamics without difficulty. Thus for units of velocity, acceleration, momentum, force, work, power, we have *o/s, o/se, lo/s, lo/se, flo/se, flo/sse*; which might be pronounced as if the 'per' were not there, and with *s* sharp. The / shows where 'denominator' elements begin, those on left of it being 'numerator' ones.

These names are here presented simply on their merits as formulæ, like those of chemistry. Thus, remembering that '*lo/se*' is formula of *poundal*, its elements are kept in mind. W = Mg is also worth looking at occasionally, as W . *lo/se* = M . *l* × *g* . *o/se*. Advantage of the formulæ in working problems is often great.

The above remarks apply to the English units. The French are easily obtained on the same plan.

Thus putting *c or i* for centimetre, *g* for gramme, and *s or e* for second, from the great variety of names which are possible the following set of unit-names seems the best choice: *i/s, i/se, gi/s, gi/se, cai/se, cai/sse,* to be pronounced as French words.

Both sets of names are to be taken as invariable in grammatical number; which is no practical inconvenience, but rather otherwise.

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14. *Exhibition and Description of Henry Draper Memorial Photographs of Stellar Spectra. By* Professor E. C. PICKERING.

The researches which constitute the Henry Draper Memorial are conducted at the Observatory at Harvard College, and consist in the investigation of stellar spectra. For this purpose Mrs. Draper has sent to the observatory the 11-inch

objective and the 28 and 15-inch specula formerly used by Dr. Draper. These specula have not yet been mounted, but preparations for doing so are in active progress. The objective above mentioned, and also an 8-inch photographic telescope, have for some time been employed in the work, which has been described in the published report on the Henry Draper Memorial. The photographs sent herewith and described below illustrate the progress of this work.

1. View of the buildings of the observatory, taken from a point to the north-west of them. The building at the right of the view contains the 11-inch Draper telescope, and the small building in the foreground at the extreme left contains the 8-inch photographic telescope.

2. Interior of the building first mentioned, showing the 11-inch telescope.

3. View of the building containing the 8-inch telescope, showing the construction of the roof.

4. View of the present state of the building now in process of construction for the 28-inch reflector above mentioned.

5. Spectra of *a Cygni* and *a Tauri* taken with the 11-inch objective and enlarged in the manner described in the Draper Memorial Report.

6. Spectra of *o Ceti* (showing bright lines) and of *a Canis Minoris.*

7. Spectra of *a Canis Majoris, a Cygni, a Canis Minoris, a Aurigæ,* and *a Bootis,* brought together upon one print for convenience of comparison. In the original negative the H line in *a Cygni* is shown distinctly double; but this effect is unfortunately lost in the process of enlargement and silver printing.

8. A copy of the Draper Memorial Report above mentioned, explaining the process employed in obtaining the spectra shown in Nos. 5, 6, and 7, and containing a plate which shows the progress made in these researches since their commencement.

9. Glass positive, showing the spectrum of *β Orionis* obtained through a layer of hyponitric fumes, for the purpose of determining the wave-lengths of lines in the stellar spectra as proposed on page 9 of the report. The principal lines of the stellar spectrum are marked with ink on the glass side of the plate. Nearly all the other lines shown are due to the fumes.

10. Glass positive of *a Lyræ* showing the H line double.

11. Glass positive of *ζ Ursæ Majoris,* showing the K line double. A faint spectrum of the star near ζ is also shown on the same plate.

12. Glass positive showing the extreme blue end of the spectrum of *a Canis Majoris.* The shorter spectrum shown on the same plate represents the same star photographed with a shorter exposure, and therefore exhibiting the detail of the brighter portion of the spectrum, which is lost by over-exposure in the spectrum showing the extreme blue end.

The spectra shown in the views numbered 5 and 6 are enlarged about five times; those in No. 7 about three times. The cylindrical lens was used in these enlargements, as described in the Report.

The glass positives Nos. 9, 10, 11, and 12 are made directly from the original negatives, and give a very good idea of the spectrum as originally obtained by the 11-inch telescope. These positives, and also the paper print No. 7, represent recent work, which is now made public for the first time.

A wide field for study is now open in the comparison of the different spectra thus obtained, and in their consequent classification. The behaviour of the metals under variations of temperature and pressure far beyond those which we can control in the laboratory are here exhibited. In the course of these researches various cosmic problems will suggest themselves, especially when we employ the greater light-collecting power of the 28-inch reflector and apply this to the peculiar spectra of some of the fainter stars. The special work for this instrument will be the study of variable stars, with a view to obtaining some knowledge of the cause of their variation. The 11-inch telescope will be largely employed in the study of the movements of stars in the line of sight.

Section B.—CHEMICAL SCIENCE.

President of the Section—Edward Schunck, Ph.D., F.R.S., F.C.S.

THURSDAY, SEPTEMBER 1.

The following Reports and Papers were read:—

1. *Report of the Committee for preparing a new series of Wave-length Tables of the Spectra of the Elements.*

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2. *Report of the Committee for investigating the Influence of Silicon on the Properties of Steel.*—See Reports, p. 43.

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3. *Third Report of the Committee for investigating certain Physical Constants of Solution, especially the Expansion of Saline Solutions.*—See Reports, p. 48.

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4. *Report of the Committee for investigating the Nature of Solution.*—See Reports, p. 55.

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5. *Report of the Committee on the Bibliography of Solution.*—See Reports, p. 57.

The President delivered the following Address:—

Ladies and Gentlemen,—It is, I can assure you, with a feeling of extreme diffidence that I take the chair to-day as President of the Chemical Section at this meeting of the British Association. When I look round me and see the many distinguished men who are prepared to take part in our proceedings I cannot but very strongly feel that the Council's choice might have fallen on a worthier representative of chemical science than myself. Having in the course of my career devoted more time and attention to technical matters than to purely scientific subjects, and having moreover arrived at a time of life when active participation in work of any kind must necessarily be drawing to a close, you must not expect from me the accurate knowledge of the present state of chemical science and the questions that are at this moment presenting themselves for solution such as would naturally be required from anyone occupying the post which I have on this occasion the honour to hold. The marvellously rapid progress of chemistry during the last twenty years has made it difficult for the most industrious cultivator of the science to keep abreast of the knowledge of the day, and for a *dilettante* like myself one may say it is next to impossible. I confess myself painfully conscious of my defects in this respect, and I shall therefore have to claim the indulgence of the Section should questions arise on which I am unable to speak with authority, or to discuss with advantage.

Considering, however, how efficiently I am supported by the gentlemen with whom I have the honour to be associated, and to whom I am sure in any case of difficulty I may appeal for assistance, I trust to be able to perform the duties of my office without discredit. I will not, however, trouble you with merely personal questions, which are always more or less tedious, but proceed with the few remarks which I wish to make, and which, if not new or instructive, may perhaps serve to entertain you during the time usually devoted to addresses of this kind.

I think you will hardly expect me, even were I fully competent to do so, to review the progress of chemistry during the last half-century, for the time at my disposal would be too short and the result at my hands, I fear, unsatisfactory. I shall prefer to call attention in a few words to the chemistry of other days as I knew it and the chemistry of the present time as known to us all, and to point out what I consider to be the chief characteristics of each. I shall then, with your permission, point out a few of the directions in which, in my opinion, the chemistry of the future will probably be developed, and in this undertaking I shall perhaps be more successful than in the other; for to discuss the history of science requires exact knowledge; but in speculating on its future the imagination comes into play, and to imagine is easier than to describe.

When I first entered on my studies, exactly fifty years ago, chemistry could hardly be called a science—it was rather a collection of isolated facts unconnected by any consistent theory covering the whole field. Most of the important elements were known, but of the exact proportions in which they combine together we were ignorant. The law of definite proportion had been generally accepted, but so imperfect were the data then at our disposal that we may say the law was rather taken for granted than proved. The atomic theory of Dalton as explaining this law had also been adopted by chemists; but it is not unlikely that this theory, then in its infancy, might by the vigorous onslaught of a man of Berthollet's acumen have been upset, and we should then have been left entirely without a guide through the bewildering labyrinth of facts. Of any connection between chemistry and physics there was in those days no question; of any but the most superficial notions regarding the effects of heat, light, and electricity on chemical substances we had no conception. The idea that chemistry could have any bearing on or connection with physiology or pathology would have been ridiculed as absurd. I can hardly think of the then state of organic chemistry without feeling amused. The condition of this branch of chemistry could hardly perhaps be called chaotic or rudimentary, for, after all, what had been done had been well done and neatly done, but the assemblage of facts of which it consisted was devoid of systematic arrangement; it resembled a cabinet of curiosities, the components of which stand in no recognisable relation to one another, or a miscellaneous collection of books placed in an orderly manner on shelves, but without any attempt at classification. As to the genesis of organic compounds, what would now be called absurd notions prevailed. I distinctly remember eminent chemists maintaining that no strictly speaking organic body, even of the simplest constitution, could possibly be formed without the intervention of the so-called vital force. The fact, then recently discovered by Wöhler, of the artificial formation of urea from inorganic substances, was considered as something almost miraculous—*i.e.*, as a phenomenon the like of which would perhaps never again recur. Without, however, entering into further details, I think I may, without fear of contradiction, assert that the main distinction between the chemistry of fifty years ago and the chemistry of the present day consists in this, that, whereas formerly the science dealt chiefly with qualitative reactions, it now occupies itself principally with quantitative determinations. To have established the fact that every chemical phenomenon may be represented in figures, denoting either number, measure, or weight, such figures, when once accurately determined, remaining constant and unchanged through all time—this seems to me the crowning glory of modern chemistry. It is the firm establishment of this principle that has transformed the face of chemistry and has made it an exact instead of a merely descriptive science.

In justice to our predecessors it should, however, be remembered that this principle, though more fully developed in our own day, was not for the first time

set up in quite recent times. The labours of Dalton, conducted on quantitative lines, were performed in this city of Manchester in the early part of this century. At the same time Berzelius was engaged in analysing the most important inorganic compounds and establishing the fact, not previously recognised, strange as it may now appear, that every well-defined substance has a definite chemical composition. But going still further back, we come to the alchemists. Now alchemy, if it has any logical basis at all, is founded on quantitative notions as regards matter. All metals, the alchemists said, consist of sulphur, salt, and mercury (these terms signifying not so much elements in the modern sense as qualities) in various proportions; hence their convertibility. Take copper, remove from it a certain proportion of its sulphurous constituent, and add more of the mercurial, and you have silver; repeat the process with silver, and gold results. At the time of which I speak, though much important analytical work had been done by Berzelius, Rose, and others in inorganic chemistry, though the veteran Chevreul had led the way in placing organic chemistry on a quantitative basis, and the composition of the most important organic compounds—thanks to the labours of Liebig and his method of organic analysis—had been ascertained, still quantitative determinations were not considered of such paramount importance as at present. In fact, scientific thought did not run in that direction, but satisfied itself, for the most part, with the study of qualitative reactions. It was still possible to see memoirs by eminent chemists containing not a single quantitative determination. Strange as it may seem, two able chemists, Boettger and Schoenbein, were living until quite recently who worked and obtained valuable results without resorting to the balance, the instrument which of all others seems the most indispensable to the chemist of to-day. The balance was indeed universally employed in my younger days, but no other instrument, properly so called, was ever seen in the laboratory. The spectroscope was not yet invented, the polariscope had not come into use; volumetric analysis was still in its infancy. Even the thermometer was but seldom used. What a different picture does the laboratory of the present day present, with its instruments of precision and its various appliances for effecting quantitative determinations of all kinds!

Whether the universal prevalence of and exclusive attention to quantitative methods in chemistry has been an unmixed good may be doubted. Who has not run with a weary eye over the long array of figures, the never-ending tables of which some modern memoirs seem to consist, and not longed for some mere description—were it only regarding trivial matters—to relieve the monotony and fix the subject treated of on the memory? That quantitative determinations given in quite precise terms may occasionally be entirely futile may be seen on referring to the history of alchemy. One of the later alchemists professes to have converted 5,400 parts by weight of copper into 6,552 parts of silver by the action of 1 part of a metal-improving substance (philosopher's stone).[1] Here we see the quantitative method applied to a purely chimerical process, elaborated from the depths of the experimenter's inner consciousness, and of no value whatever. Much of what is at the present day carefully worked out and presented to the world in numerical form may, like this statement of the alchemist, pass away and be forgotten. This may possibly be the case with the numerous carefully made analyses of water which we now meet with, and which we would gladly exchange for a few decided qualitative tests of its hygienic properties. In the case of air and water it is not the minuteness of the noxious matter which causes doubts to arise, but the absence of any decided and undoubted chemical characteristics of the impurities present. It is probable that a refined sense of taste, uncorrupted by the luxurious indulgences which civilisation has introduced, would be able to detect differences in drinking water which might escape the attention of the most consummate analyst.

Whatever objections may, however, be entertained to the application of quantitative methods in natural science, to the exclusion of others, it is certain that important results have flowed from their adoption, insomuch that we seem to have arrived at the conclusion that the expression of quantitative results is the be-all

[1] Kopp, *Die Alchemie.*

and end-all of science; that all differences are merely quantitative; that there is no such thing as mere quality. The whole philosophy of our age is expressed in this one proposition: All differences within the sphere of our experience are quantitative. It is the basis of Darwinism, if I am not mistaken, and underlies many of our political and social theories. Of course it is a mere assumption if stated generally, for the phenomena that admit of purely quantitative expression are few in number compared with those that do not; but then it is surmised, and with some degree of probability, that the vast region outside the quantitative sphere will in time come to be included within it. The past history of science seems to render this likely in the future. The science of chemistry has so far, however, presented an insuperable barrier to the general adoption of this view, and will continue to do so as long as the so-called elements remain what we now admit them to be—indestructible, immutable, inconvertible. It is possible to denote all the known properties of gold and silver, their atomic weight, specific gravity, hardness, malleability, action towards heat, light, and electricity in precise numbers with reference in each case to a certain standard, and yet we cannot say that silver minus a little of this, plus a little of that, constitutes gold—the two elements are essentially and radically distinct. Unless we admit with the alchemists that by taking away a little of A and adding a little of B we can convert one metal into another, one element into another, the quantitative method must fall short of its complete development in chemistry. Numerous attempts have, therefore, been made to show the theoretical probability, even if it should not be possible to prove it experimentally, of the so-called elements being really compound bodies, or at least of their containing a basic matter common to all. My predecessor in this chair has endeavoured to show in the brilliant address delivered to this Section on the occasion of the last meeting of the Association that the barrier hitherto presented to us by the intractability of our present elements may be overcome, and has adduced experimental illustrations in favour of his view of the compound nature of the elements. Mr. Crookes has called to his aid the doctrine of evolution, which has proved so valuable an instrument in the hands of the biologist, maintaining that the elements, like the species of plants and animals, were gradually evolved by some process of condensation from a primordial matter called by him 'protyle,' each step in the process being represented by a distinct element. This is doubtless taking very safe ground, for if the process of evolution was the same in the inorganic as it is supposed to have been in the organic world, the process can never be repeated, and we shall, therefore, never be in a position to illustrate it experimentally. I may, however, have misunderstood what Mr. Crookes meant to convey, and, if so, must apologise for misrepresenting his views. Granting, however, the possibility of our resolving our present elements, were it in theory only, into modifications of one basic material out of which they have been evolved, the question would still remain to be answered, What has caused this primordial matter to be split up into groups and forms having distinct and opposite qualities? and when this question is answered, if it can be answered even in a problematical way, then other questions would arise, until by degrees we should arrive at the confines of physical knowledge and find ourselves in the region of metaphysics, where scientific reasoning ceases and thinking for scientific purposes becomes unprofitable. Excursions into this region would indeed be very useful if on returning to physical regions we could every time bring back with us an instrument as potent and far-reaching as the atomic theory has proved to be, a theory which still remains the basis of all our reasoning in chemistry, but then the atomic theory has been quite an exceptional instance. Metaphysical speculation, such as the Naturphilosophie of the Germans has dealt in, has, generally speaking, been utterly barren in natural science.

I will not on the present occasion dwell on the vast addition made to the number of useful and beautiful substances by chemists during the last fifty years. Their number is legion, and their mere description fills volumes, whereas half a century ago a dictionary of moderate size would have sufficed for the purpose. Among these newly discovered substances none are more remarkable than the metals rubidium, cæsium, thallium, indium, gallium, the existence of which was revealed by the spectroscope, and which, indeed, would probably have remained

unknown but for the labours of Bunsen and Kirchhoff in perfecting and applying that instrument.

I must not, however, omit all reference to a department of chemistry which has been, one may almost say, created within the time to which I am referring—I mean that of synthesis. When I began to study chemistry we only heard of analysis; of synthesis, so far at least as regards organic bodies, we only dreamt as a remote and unattainable region. The only instance then known of the synthesis of an organic substance was that of urea by Wöhler. Synthesis was, indeed, supposed to be an essentially vital process effected under the influence of the vital force, and quite outside the sphere of the chemist. Since then what marvels have we not seen? Alizarin and purpurin, the colouring matters of madder, have been prepared artificially by Graebe and Liebermann, indigo by Baeyer, not to mention bodies of simpler constitution obtained by comparatively less complicated processes. We are honoured to-day by the presence of Professor Ladenburg, who has succeeded in artificially preparing coniin, the alkaloid to which hemlock owes its poisonous properties; the first natural alkaloid, indeed, which has been obtained artificially. Looking back at what has been achieved I think we may entertain the confident anticipation that all the most important organic bodies—acids, alkaloids, and neutral substances—will, in course of time, be obtained in a similar manner, though of one thing we may be pretty sure, viz., that we shall never succeed in forming any really organised matter as distinct from organic. The term organic matter is in fact only employed for the sake of convenience, and as an expression handed down to us from former days, since so-called organic compounds are subject to the same laws with regard to composition as the bodies which we name mineral or inorganic, but organised matter such as we find constituting the vessels of plants and animals is a different thing. The protoplasm contained in the vegetable and animal cell is something very distinct from the same matter after the death of the organism, but the difference between living and dead matter is not of a chemical nature. In referring to chemical synthesis I cannot refrain from expressing regret that so little has hitherto been done in the artificial production of minerals with a view to elucidating the processes by which they were formed in nature, but it is possible that more has been done in this direction than I am aware of, since this is a department of chemistry with which I am not familiar. It is certain that inorganic chemistry generally does not now receive the attention which it formerly did. The exclusive devotion to the chemistry of the carbon compounds which we find in most of our laboratories at the present day may, however, be accounted for when we see the brilliant results to which the study of those compounds has led.

After these few remarks on the development of chemistry during the last fifty years, of which I know a little, it may seem presumptuous on my part, in the presence of some of the most eminent chemists of our day, whose opinions must be of infinitely more value than mine, to say anything about the future of our science and the direction it will probably take. Nevertheless, trusting to your kind indulgence, I will venture on some speculations in this direction, which, if they do not instruct the younger members of the Section, may serve to amuse their seniors, and at all events will refer to subjects on which some thought is well bestowed.

As regards the future of chemistry, the question has frequently suggested itself to me as it has doubtless done to others—Will chemical science go on expanding and developing during the next few generations as it has done in the course of the last hundred years? Will discovery follow discovery, and fact be added to fact, until the record occupies not a few volumes only, but a whole library? Will systematic chemistry, *i.e.*, the history and description of all possible combinations of the elements, have any limits? I am inclined to answer in the negative. All human institutions pass through the same phases; they have their rise, they culminate, and decay; and I do not see why the science of chemistry should form an exception. Moreover, it is a natural law that whatever develops rapidly also declines rapidly, and the development of systematic chemistry since the commencement of this century has been perfectly unprecedented. I think it probable that in the course of time, at the rate at which we are now progressing, nearly all possible compounds will have been prepared, all the most important chemical facts will

have been discovered, and pure chemistry will then be practically exhausted, and will be in the same condition as systematic botany and mineralogy now are. New compounds will now and then be discovered, just as new plants and new minerals now are, but nothing further will be brought to light that will affect the theories at which we shall then have arrived, whatever they may be. All the material with which the science has to deal having then been brought together, what will happen? Will chemical science cease? Will chemists, satisfied with past achievements, cease to work, confining themselves to practical questions and the history of the days gone by? I think not. The science will continue to develop, but it will be in other directions than those previously pursued. The exhaustion of systematic botany has not put an end to botanical science, for vegetable physiology has opened a wide field to the botanist, one that will take a long time to explore thoroughly. To indicate the directions which chemical science will take in its various applications to other departments of knowledge, as, for instance, in connection with the study of the physical properties of matter, or in elucidation of the chemical processes whereby minerals have been formed, or those through which geological strata have passed in bygone ages, would not be within my competency, as I should have to touch on subjects with which I am not familiar; but I may be permitted to refer in a few words to a subject, with which, by reading at least, I have become better acquainted, and which seems to me to offer a wide field to the investigator who shall come well provided with physical and chemical knowledge to its cultivation. I allude to the processes whereby the substances constituting the various organs of plants and their contents are formed, and those again to which the decomposition and decay of vegetable matter are due; a subject as to which our knowledge is quite elementary, but which, it seems to me, admits of an extension and development of which we have at present not the least conception.

De Saussure, it is well known, first discovered the fact that plants under the influence of light absorb carbonic acid and give off oxygen, the inference of course being that the carbonic acid and the water present are decomposed, the carbon of the former and the hydrogen of the latter going to form the various organic constituents of the plant, while the oxygen or a part of it is set at liberty and poured into the atmosphere. The facts as they stand are simply these: what the plant requires for its subsistence is carbonic acid, water, nitrogen in some form (presumably that of a nitrate), certain bases—potash, lime, magnesia, iron oxide, and phosphoric acid. Out of these it constructs the whole of its organic frame, its cells and their contents, re-arranging the elements of which its food consists in such a manner as to convert inorganic into organic matter, *i.e.* changing bodies in which the affinities of the atoms are thoroughly satisfied into such as contain them in a state of more or less unstable equilibrium, and therefore liable to alteration when their atoms are allowed to act in accordance with their natural affinities. More than this we do not know; our ignorance of the several steps or stages of the process, if there are any such steps, is complete; all that has been added to the general statement just given is mere speculation. Yet it is impossible to remain satisfied with the present state of our knowledge on the subject. Accordingly numerous attempts have been made to bridge over the chasm which separates the inorganic and organic worlds, not indeed to show that the change does not involve the creation, as was once supposed, of new matter—for this was proved long ago—but to exhibit in its details the hidden mechanism which produces it—but hitherto without success. We know that light is essential to the process of assimilation in plants, since the process does not go on in the dark; but this fact does not help us to an explanation, for light in this case is a mere stimulant, and never produces the same or similar effects outside the vegetable organism. Liebig and others have attempted to show that the process of assimilation in plants commences with the formation of some simply constituted body, such as oxalic or formic acid, with the elimination of oxygen, out of which by condensation and further separation of oxygen more complex bodies, such as sugar, fats, &c., are formed; but there is not the slightest evidence at present in favour of this view. The first product of assimilation that is distinctly recognised is starch, a highly complex organic, one might almost say an

organised body, which appears at once with all its characteristic properties, like Minerva springing fully armed from the head of Jove. If we are to adhere to the facts so far observed, we must conclude that the plant does not proceed as we should do in the laboratory, beginning with the more simply constituted compounds and advancing to the more complicated, but that the reverse process is the one actually adopted, the supposed intermediate products being in fact the result of retrogressive metamorphosis. This conclusion is, however, so much opposed to ordinary chemical views that one cannot feel surprised at the constantly repeated attempts to clear up the question. There can be no doubt indeed that much here remains to be done and to be discovered.

Intimately connected with this subject is that of chlorophyll, the green colouring matter of leaves, which is always found wherever the process of assimilation in plants is going on, and nowhere else, and is therefore doubtless an essential factor in the process. What part it plays in this process is, in my opinion, still unknown. Its action is probably in part chemical, in part physical, and this adds, it may be, to the difficulty of understanding it. It is generally supposed that it is chlorophyll which by its direct action on the carbonic acid and water with which it comes into contact leads to the formation of organic matter with elimination of oxygen. But this is, I think, a mere assumption—an error due, like many others, to a mistaken use of terms. The chlorophyll of chemists is simply an organic colouring matter, like alizarin or indigo, but being in the vegetable cell intimately associated with other matters, vegetable physiologists have attributed to the action of one, and that the most obvious, constituent what is really due to the complex, perhaps even to some quite other constituent of the complex. It is difficult to understand how the chlorophyll of chemists can be endowed with the remarkable and exceptional properties attributed to it by physiologists; it is a chemical entity, nothing more. It may indeed be said that chlorophyll only acts as it is stated to do when enclosed within the vegetable cell, but this merely amounts to saying that its action is not purely chemical, but is controlled by the vitality of the cell, which, I suppose, means the action of the protoplasm. If chlorophyll is the agent whereby the decomposition of carbonic acid and water is effected, how, it may be asked, is the agent itself produced? It does not come from without; the plant must be able to form it in the first instance. We are told by vegetable physiologists that the coniferæ when raised in total darkness from seeds produce chlorophyll. In light or in darkness I am convinced it is the same; the plant forms chlorophyll as a means to an end. What the end is we know; it is the assimilation of carbon and hydrogen to form organic matter. How does the chlorophyll assist in attaining this end?

In propounding a new theory in reply to this question I venture to claim your indulgence, such as has been accorded to some of my predecessors and others who at these meetings of the British Association have been permitted to make statements and use arguments of a novel or paradoxical character, which, if they effect nothing else, at least afford a relief to the usual routine of scientific reasoning. My experiments on chlorophyll have led me to infer that the constitution of that body is much less simple than it is generally supposed to be. I do not mean by this that chlorophyll is a mixture in the usual sense; everyone who has paid any attention to the subject knows that ordinary chlorophyll consists of several colouring matters, some of which are yellow, not to mention fatty matters which are unessential. What I mean to say is this, that the pure green substance, the chlorophyll *par excellence*, does not belong to the same class of bodies as alizarin or indigo, but contains three elements, each of which is essential to its constitution, one being a basic nitrogenous colouring matter, the second a metal or a metallic oxide, the third an acid, the three together constituting green chlorophyll. The basic colouring matter is a body of very peculiar properties; it is the phyllocyanin of Fremy: the metal may be iron or zinc, the acid I will suppose to be carbonic acid. Now the plant having formed its colouring matter, the metallic oxide being present in some form or other, and the carbonic acid being supplied by the atmosphere, all the necessary conditions co-exist for the formation of chlorophyll. The compound is an unstable one; it easily parts with its carbonic

acid, giving it up to the protoplasm or whatever the agent may be that effects its actual decomposition under the influence of light. The advantage of this arrangement would consist in this, that the carbonic acid would be presented in a more condensed state to the agent which effects its decomposition than if it were merely contained in a watery solution, but more loosely combined, and therefore more easily accessible than if it were united to a strong base such as potash or lime. The carbonic acid having been disposed of, the other two constituents would be in a state to take up fresh quantities of carbonic acid and so on. Chlorophyll would therefore act as a carrier of carbonic acid in the plant, just as hæmoglobin serves to convey oxygen in the animal economy. Numerous objections may of course be raised to the theory of which I here give an outline; I only throw it out as a tentative explanation, showing that the function of chlorophyll may be, in part at least, chemical, and that we need not suppose it to be endowed with the marvellous and exceptional powers usually ascribed to it. Other and more probable explanations will doubtless suggest themselves when this difficult subject has been more thoroughly worked out. Eventually, too, it will be found, I imagine, that physical forces as well as chemical affinities play a part in this as in every other process of the vegetable economy. In the case of chlorophyll there can be no doubt that the green colour and the peculiar behaviour towards light have something to do with its action, but on this point it is not necessary for the chemist to pronounce any opinion. I may take this opportunity of mentioning the important experiments of Sachs and Pringsheim on the optical properties of chlorophyll in their relation to assimilation in plants, as they are probably not so well known to chemists as to botanists.

What I have said may serve to show that the very first steps of the process whereby organic or organised matter is formed in plants are hardly understood. We understand still less the further steps leading to the production of the more complex vegetable bodies—acids, alkaloids, fatty matters. Granted that we were able to trace the formation in the plant of a compound of simple constitution, such as oxalic or formic acid, how far should we still be from understanding the building up of such compounds as starch, albumen, or morphia? The syntheses so successfully and ingeniously carried out in our laboratories do not here assist us in the least. We know the steps by which alizarin is artificially produced from anthracene; but can anyone for an instant suppose that the plant commences in the same way with anthracene, converting this into anthraquinone, and having acted on the latter first with acid, then with alkali, arrives at last at alizarin? Indeed the plant never contains ready-formed alizarin at all. What we observe from the commencement is a glucoside, a compound of alizarin and glucose, which, so far as we see, is not gradually built up, but springs into existence at once. When we think of the complicated process by which indigo is produced in the laboratory with the various substances and appliances required, and then see how in the minutest seed-leaves of a plant like woad a still more complex substance, indican, is found ready-formed, we stand confounded at the simplicity of the apparatus employed by the plant, and are obliged to confess that we have no conception of the means whereby the end is attained. The same difficulties occur in other cases, and it will therefore probably be conceded that the synthetic processes carried on in plants, from the first step to the last, are not in the least understood.

It might be supposed that after all the labour and attention bestowed on the inorganic constituents of plants we should know something of the part played by these constituents in the processes of assimilation and nutrition, but here the obscurity is as great as elsewhere. We know by experiment that certain inorganic matters—potash, lime, magnesia, iron oxide, phosphoric acid—are essential to the growth of plants; but of their mode of action, or of the reason why certain plants require potash salts, others lime, and so on, we know nothing. Phosphoric acid is no doubt an essential constituent of the protoplasm of the plant; but why cellulose, of which the various organs chiefly consist, should require mineral matters, which do not enter into its composition, for its formation and building up, is still a mystery.

The department of chemistry which relates to the decomposition of organic and

organised matter presents problems almost as difficult of solution as those relating to their formation and building up; that is to say, the phenomena observed do not apparently obey the same laws as those prevailing in the inorganic world. When I began my chemical studies the difference in this respect between mineral and organic compounds was less clearly seen than at present. The conversion of alcohol into acetic acid, the putrefaction of animal and vegetable matter were thought to be simply due to oxidation; they were phenomena, it was supposed, exactly similar to the rusting of iron, the tarnishing of metals, the fading of colours. That a third body was required to initiate and continue the process of decomposition, that organic matter in contact with purified air would remain unchanged for any length of time—was not known nor suspected. I am not quite sure whether spontaneous decomposition—*i.e.* the splitting up of a complex body without the intervention of an external agent—might not at that time have been considered possible. In order to explain the phenomena of fermentation, the decomposition of sugar into alcohol and carbonic acid, for instance, we had only the theory of contact—devised by Berzelius and Mitscherlich, the latter of whom used to expatiate on the subject at great length in his lectures. When this ghost of a theory was laid by Liebig, who suggested an intelligible explanation of the phenomena in accordance with the facts then known, it was felt to be quite a relief, as affording a resting-place—if only a temporary one—for the mind. The brilliant researches of Pasteur, which have thrown so much light on the action of the insoluble organised ferments, I need only refer to, as they are so widely known, even outside scientific circles; and since also investigations such as his cannot be discussed without some reference to biological questions, which cannot be entered on here. I will confine myself therefore to a few remarks on the unorganised or soluble ferments, one of which I had occasion to examine when engaged in investigating madder and its colouring matters. These ferments, the type of which is diastase—a substance found accompanying starch in the seeds of plants—are soluble in water, perfectly neutral, devoid of all definite form, and though apparently inert, able when acting within the sphere in which Nature has placed them to cause changes and decomposition of the most profound character. Their action excludes everything in the shape of vitality, and yet it is as mysterious and unaccountable as anything that the vitality of the organised ferments is able to effect. Indeed, in vegetable, and especially animal, organisms they seem expressly intended for the attainment of certain ends necessary for the well-being, or even the existence, of the organism, insomuch that it has been supposed, with some show of reason, that it is to bodies of this class existing within the cells of organised ferments, but not separable by any means at our disposal, that the changes produced by the latter are really due.

A great deal of attention has been paid to the products and results of fermentation, but very little hitherto to the *modus operandi* of the ferments themselves, and yet this seems to me to offer a wide field for interesting research, especially in the case of those of the soluble class, which are easily prepared, and can be manipulated in the laboratory like any chemical substance without the tedious precautions and preliminary operations necessary in the case of the organised ferments. In what way, it may be asked, do these soluble ferments produce the effects peculiar to them? Is the action essentially chemical, or is it due to physical causes as well? Is the quantity of fermentable matter acted on by a certain quantity of ferment unlimited in amount, or are there limits to that amount somewhere? Does the ferment itself undergo any change during the process of fermentation, or is it the same afterwards as before and capable of acting on fresh quantities of fermentable matter? When a ferment is replaced by a strong mineral acid, the products of decomposition being the same, is the *modus operandi* in both cases alike, or must a different explanation be in each case sought? These questions have never been satisfactorily answered, and await solution. I know of only one attempt to show what actually takes place during a process of fermentation set up by a soluble ferment.

The experiments of Wurtz[1] on papaïn, the soluble ferment of *Carica papaya*,

[1] *Comptes Rendus*, 91, 787.

led him to the conclusion that the fibrin on which it is made to act combines in the first instance with the ferment itself, the latter after the hydration of the fibrin is completed being again set at liberty, and then able to act on fresh quantities of fibrin. Thus, according to Wurtz, the action is found to be the same as that of chemical agents, properly so called, such as sulphuric acid, of which minute quantities may exert a hydrating action in consequence of the transitory formation of compounds which are constantly being produced and again decomposed.

There is another question referring to these soluble ferments to which in the present state of our knowledge it is impossible to frame a probable answer, viz., why does it so frequently happen that each ferment exerts a specific action, an action peculiar to itself, this affording in fact, in the absence of any marked chemical characters, the only means by which they can be distinguished one from the other? Why does one ferment act on starch only, while the function of another consists in the hydration of fibrin, that of another in the decomposition of a glucoside, and so on? In accordance with the explanation of Wurtz, we should say that a specific ferment is one capable of combining only with the body on which it is to act, and with no other. I was led to ask this question when engaged in the examination of the colouring matters of *Rubia tinctorum*. The root of this plant, the madder of commerce, contains glucosides, which, though coloured, are quite devoid of tinctorial power. Nature has at the same time placed in the root a peculiar ferment, which, coming into contact with these glucosides at a certain temperature, effects their decomposition, splitting them up into glucose and true colouring matters. Now this ferment is a body *sui generis* and cannot be replaced by any other ferment that I have tried; its action is specific. Why Nature should have deposited this body in the recesses of the plant for the express purpose of acting on certain glucosides and forming colouring matters, the object of which, so far as the economy of the plant is concerned, can only be guessed at, is difficult to understand. One is inclined in such a case to revert to the old-fashioned doctrine that some natural processes were devised for the use and delectation of man. It is quite certain in the case of madder that had it not been for its peculiar ferment erythrozym, the valuable tinctorial properties of the root, which have for centuries been applied in the production of that splendid dye Turkey red, would have remained unknown perhaps to the present day, since the only efficient substitute for the natural ferment is a strong mineral acid, and such acids and their uses were unknown in former days.

I am inclined to think that some of the younger chemists and physiologists of to-day may live to see the time when all the at present mysterious and unaccountable processes going on in the organisms of plants and animals, including those of fermentation, will be found to obey purely physical and chemical laws. To the biologist it may seem derogatory to the dignity of his science to have the principle of vitality, which has so long reigned supreme, dethroned and replaced by hard, unbending law. Such, however, is not the opinion of that distinguished botanist Sachs, who says, referring to this very point:—'Der Organismus selbst ist nur die aus verschiedenen Theilen bestehende Maschine, die durch weitere Eingriffe äusserer Kräfte in Bewegung gesetzt werden muss: von ihrer Struktur hängt es ab, welchen Effekt diese äusseren Kräfte an ihr bewirken. Es würde einen sehr niedrigen Horizont wissenschaftlicher Bildung verrathen, in diesem Vergleich eine Herabsetzung des Organismus sehen zu wollen, denn in einer Maschine, wenn auch nur von Menschenhänden gemacht, liegt das Resultat tiefsten und sorgfältigsten Nachdenkens und hoher Intelligenz, soweit es ihre Struktur betrifft, und wirksam sind in ihr schliesslich dieselben Naturkräfte, welche in anderer Combination die Lebenskräfte eines Organs darstellen. Die Vergleichung des organischen Lebens mit unorganischen Processen kann nur dann als eine Erniedrigung des ersteren gelten, wenn man so thöricht gewesen ist, die letzteren als etwas Niedriges und Gemeines aufzufassen, während die unbegreifliche Grösse und Durchgeistigung der Natur in beiden Fällen sich gleichartig offenbart.'[1] The time may be far distant when these views of the great botanist shall be universally accepted; but they will, I think, sooner or later prevail.

[1] *Vorlesungen über Pflanzenphysiologie.*

The little known territory which separates the domains of chemistry and physiology will, in my opinion, offer a wide and interesting field for research, after that of pure chemistry shall have been exhausted or lost its interest. Most important problems connected with life and its relation to the inorganic world there await solution, and I confess that I am inclined to envy the young investigator who, coming provided with an ample store of chemical and physical knowledge, shall apply himself to the solution of these problems. The pleasures derived from the successful pursuit of such studies belong to the highest and purest that we are able to conceive. I can, however, only repeat what has so often been said before, and what the young man of science should not forget, that a life devoted to research only involves no material rewards; it certainly never secures wealth, sometimes not even honour nor fame. Looked on with indifference or even dislike by the State and the general public, all that the man of science can certainly look forward to at the close of his career is the addition at his hands of a few stones to the vast edifice of Truth, and the consciousness of having attained a higher stage of intellectual insight.

You may probably expect me, before I conclude, to make some reference to technological matters, to the various chemical arts and manufactures for which the Manchester district is noted. At the last meeting of the British Association in Manchester a report on the condition at that time of manufacturing chemistry in the South Lancashire district, by Sir Henry Roscoe, the late Dr. Angus Smith, and myself, was laid before the Chemical Section. A similar report showing the progress made in chemical technology since that time would have been interesting. Great changes have taken place during the period that has elapsed, especially as regards the alkali trade, and quite a new branch of industry has been developed, that of the coal-tar colours. A description of these new features of our chemical industry with statistics of production would therefore have been acceptable. The idea of a report had, however, to be given up on account of the difficulty of obtaining reliable information as to details, and in these matters it is the details principally which are interesting, the general features of the subject being well known. It can hardly be a matter for surprise, I think, that our manufacturers, considering the active competition to which they are exposed, and the disadvantages under which they labour in consequence of the exclusiveness of foreign nations, should be loth to furnish information which would benefit their rivals in trade. Several interesting papers on branches of chemical industry by gentlemen well versed in them will, however, be read before the Section, and these will, to a great extent, make up for the want of a general report. In the Chemical Section of our Jubilee Exhibition, too, you will see a very fine collection of chemical products, more extensive and beautiful, perhaps, than any previously brought together, and these will give you a good idea of our industrial activity. It would have been interesting to witness step by step some of the processes employed in the manufacture of these various products, but this, I am sorry to say, must not be expected generally.

To some it may seem that this Jubilee Exhibition shows the manufacturing industry and prosperity of this district at least at their highest state of development; that they are now at their meridian, and in the future are doomed to decline. If this be so—and there are certainly indications which seem to favour this view—it would be well for those whose visits here are only occasional to take especial note of the present state of things so as to be able to compare their impressions when they next visit us with those now received, since gradual changes in communities, as in individuals, are more patent to casual observers than to those who are always on the watch.

From some points of view the signs of the times are certainly not encouraging. It should not be forgotten that the manufacturing prosperity of this district depends to a great extent on the ample supply of a product which is brought to us at some cost from tropical and semi-tropical countries to be re-exported in the shape of manufactured goods. A political convulsion abroad, and this, unfortunately, is a casualty that may at any time be expected, or even the determination on the part of other nations to starve us out, however short-sighted such a determination would be, might cut off our supplies and disable us permanently as we were partially dis-

abled twenty-five years ago. If to this be added the fact that foreign nations are becoming increasingly hostile and exclusive commercially, we cannot feel surprise at the dismal forebodings entertained and the confident predictions of decline uttered by some who claim to know all the facts. I ought to apologise for alluding to so gloomy a subject on the occasion of this to a great extent festive gathering, but then men of science like to look at a question not only from a hopeful but from every point of view. Fortunately on this question they are not called upon to pronounce any opinion one way or the other.

Should this be the last time that Manchester shall entertain the British Association in the day of its prosperity, I can only say with the German poet—

Schliesst den Kreis und leert die Flaschen
  Diese Sommernächte feiernd,
Schlimme Zeiten werden kommen,
  Die wir auch sodann ertragen.

Whether in prosperity or adversity I feel sure that this city will always endeavour to entertain its visitors to the best of its ability. On the present occasion I may, with confidence on the part of the chemical world of Manchester, offer to the many friends from near and far who honour us with their presence at this meeting a most hearty welcome.

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6. *Preliminary Notice of a Re-determination of the Atomic Weight of Gold, with some remarks on the present State of our Knowledge as to the Determination of Atomic Weights in general. By* Professor J. W. Mallet, *F.R.S.*

For the last two years experiments had been in progress looking to as exact a determination as possible of the atomic weight of gold, for which until recently there had been but very few data. Within the last few months the results had been published of two researches on this subject by others, namely, by Krüss in Germany, and by Thorpe and Laurie in England. Yet Mr. Mallet's work was continued, since there can scarcely be too much verification of important constants, and the methods adopted were not altogether the same as those used by the other chemists named, all whose results were obtained by essentially one and the same process. Such liability to error as belongs to this process was pointed out.

The author's own work had not yet reached the point of giving final results for publication, but the probability seemed to be that a rather higher value would be found for the atomic weight in question than that assigned by other experimenters.

It was suggested that the most important direction for advance in our knowledge of atomic weights is that of endeavouring to eliminate '*constant errors*,' as distinguished from mere personal or casual errors of experiment. The latter we have been taught, by the example of Stas, to reduce to very small values by minute and elaborate precautions. But the former are always to be suspected, and all conceivable means should be used to avoid them. Among the most important of such means the following were pointed out:—

1st.—Resort in every case for the purification of materials used to 'fractional' methods, assuming materials to be pure only when earlier and later fractions give sensibly identical results.

2nd.—Great care in the study of the reactions depended upon for final determination of atomic weights, looking especially to any possibility of the occurrence of secondary or subsidiary reactions.

3rd.—Adoption of methods by which (*a*) the atomic weight to be determined may be connected *directly* with that of hydrogen, or (*b*) if connected indirectly, by the intervention in each single determination of as *few* other elements, but in determinations by different methods of as *many* other elements as possible of supposed well-known atomic weight.

Under this last head a method was described which had been resorted to by the author in his work on the atomic weight of gold, affording a direct connection with

that of hydrogen; a method which the author believed capable of more extended application in the determination of the atomic weights of other elements. Zinc was prepared of a high degree of purity, and a given weight of the metal having been dissolved in dilute sulphuric acid, the amount of hydrogen evolved was determined by volume. A solution of auric bromide or chloride as pure as possible was treated with a known quantity of the same zinc, more than sufficient for the precipitation of the gold; the excess of zinc was dissolved by dilute sulphuric acid, and the volume of hydrogen given off was determined. The precipitated gold was carefully collected, washed, dried, and weighed. The difference between the volume of hydrogen which the zinc gave when thus partly used to replace a known quantity of gold, and the volume which it would have given if replacing hydrogen only, taken in connection with Regnault's determination of the relation of weight to volume for hydrogen, afforded of course the data needed for a direct comparison of the weights of gold and hydrogen concerned. It was pointed out that in applying this process the weight of the gold salt in solution need not be known, and that the method is not dependent upon a knowledge of the atomic weight of the halogen, combined with the gold, or of the atomic weight of zinc, and does not even require that the zinc shall be of assured purity, provided only it be uniform in character, so that a given weight of it can be depended on to yield always the same quantity of hydrogen, and there be no impurities present capable of interfering with the collection of the precipitated metallic gold in a state of purity.

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7. *The Atomic Weight of Zirconium.* *By* G. H. Bailey, *D.Sc., Ph.D.*

The previous determinations of atomic weight of this element were made by Berzelius (89·25), Hermann (88·8), Marignac (90·54). The earlier results were doubtless vitiated by the presence of iron and of the cerite earths, whilst Marignac's determination is open to objection from the character of the salt (potassium zirconium fluoride) which he used. In the present determination, zirconia was prepared from North Carolina zircons by three independent methods. This was dissolved in sulphuric acid and the sulphate was crystallised out. This salt becomes normal and constant in weight by heating some hours at 400°, the temperature at which it begins to decompose being 470°. The relation of zirconium sulphate to zirconia gives a ratio from which the atomic weight is calculated and the value thus obtained agrees more nearly with that of Marignac. The author proposes to make further determinations, using the tetra bromide.

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8. *Torsion Balances.* *By* Dr. A. Springer.

Light frames are made and then stiffened by wires or flat bands being tensioned over them. The beam is firmly clamped to the bands in such a manner that its centre of gravity is above its point of support; this tends to tip the beam, thus equilibrating the torsional resistance of the fulcrums. We thus have the torsional resistance exerted to keep the beam horizontal, and the high centre of gravity tending to tip it out of the horizontal.

The adjustment of the position of the centre of gravity is most easily made by having an adjustable poise placed immediately above the central torsional wire. In order to do away with the necessity of alignment of support, a secondary beam is attached to the first in such a manner that both beams tending to tip in the same direction remain stationary owing to their having opposite and equal moments.

On this principle scales are constructed which can be used on rolling ships or in buildings where there is considerable jarring. In all the 'Torsion Balances' there is permanence of adjustment, consequently repeated weighings will give like results.

Various 'Torsion Balances' were shown illustrating the principles involved, as well as showing how equal sensitiveness can be obtained with any load.

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9. *Integral Weights in Chemistry.* *By* T. Sterry Hunt, *LL.D., F.R.S.*

The author began by insisting that changes of state, such as the condensation of vapours to liquids and solids, the vaporisation of these, the fusion of solids, and also the transformations alike of gaseous (liquid and solid) species, whether elemental or compound, are comprehended under the general head of chemical metamorphosis. He considered the relations of all these changes to temperature and pressure, and noted that while passing alterations in volume alike in solids, liquids, and gases are not chemical but dynamical, the phenomenon of elasticity in gases and vapour is a manifestation of chemical change, giving rise to new species which are unstable at the existing temperature. He next remarked the difference between metamorphosis, or homogeneous change, and metagenesis, or heterogeneous change, in both cases including alike integration and disintegration. He insisted upon the subordination of all chemical changes to simple relations of measure, number, and weight, as appears from the facts of definite and multiple proportions and from progressive series.

Regarding the chemical species as an integer, and rejecting the language of the atomic or molecular hypothesis, the author designates the equivalent or so-called molecular weight as the integral weight of the species. This weight for gases and vapour is calculated from that of hydrogen gas as the unit of weight, the specific gravity of such bodies varying directly as their integral weights. It is farther maintained that the law of volumes governs equally the combination of gases and vapours, and their condensation into liquid and solid integers. These have consequently very high integral weights, which may be calculated like those of gaseous species by comparing their specific gravities with that of hydrogen gas—which is the true and natural unit of specific gravity for all species alike—or else with that of water, which is generally assumed as the unit of specific gravity for liquid and solid species. Water is generated by the integration of 1,628 volumes of water vapour at 100° and 760 mm. into one volume of the same temperature. Direct determination of the weights of equal volumes of steam and water shows that the integral weight of the former is not 18·0, but very nearly 17·9633—corresponding to the corrected number for oxygen—so that the integral weight of water, $1628\ (H_2O) = 29244$; that of steam $H_2O = 17{\cdot}9633$, and that of hydrogen gas $H_2 = 2$.

The question of the contraction of water from 100° to 15° and 4°, the points generally assumed for the unit of specific gravity, was next considered, and also the fact that the density of all liquid and solid species should theoretically be taken at the highest temperature which they can sustain without chemical change. But in view of the errors incident to the determination of such densities in solids, and their relatively small coefficients of expansion, it is believed that those taken at ordinary temperatures give us sufficiently near approximations.

The high integral weights thus fixed for liquids and solids in which the unit of specific gravity for gases is multiplied by 29244 are in accordance with the notion of great condensation, or so-called polymerisation in such species, which has been maintained by many chemists, and notably by the author since 1853. It now becomes possible, by fixing their integral weights, to give their true formulas for all species, and to show that even the salts of the ammoni-cobalt bases, and those of the so-called 'complex inorganic acids' of Wolcott Gibbs have higher integral weights than was before suspected. The relations of the process of condensation or integration to hardness and to chemical indifference were noticed in conclusion, and allusion was made to the more detailed discussion of this subject in the author's lately published volume, entitled, 'A New Basis for Chemistry,' and in a more recent essay on Chemical Integration, in both of which it is maintained that these are, like specific gravity itself, functions of the integral weight.[1]

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[1] Published *in extenso* in the *Phil. Mag.* for Oct. 1887.

10. *On the Action of Light on the Hydracids of the Halogens in the presence of Oxygen.*[1] *By* ARTHUR RICHARDSON, *Ph.D.*

The author pointed out some of the conditions which influence the decomposition of the gaseous hydracids of chlorine, bromine, and iodine, in presence of oxygen when exposed to sunlight.

Dry, or even partially dry, hydrochloric and hydrobromic acids are unacted on by sunlight, when mixed with varying proportions of oxygen.

Perfectly dry hydriodic acid, on the other hand, readily decomposes when exposed in the presence of oxygen. The gases when saturated with moisture are shown to suffer decomposition to a degree dependent on the amount of oxygen with which they are mixed, in excess of that required for the complete oxidation of the hydrogen of the acid. In the cases of hydrochloric and hydrobromic acids, the amount of decomposition is very small when enough oxygen only is present to unite with all the hydrogen of the acid, the amount of decomposition increasing as more oxygen is added.

In a note the author showed that phosphonium bromide and iodide are formed by the action of light on moist amorphous phosphorus and hydrobromic or hydriodic acid.

FRIDAY, SEPTEMBER 2.

The following Papers and Report were read:—

1. *On the Present Position of the Alkali Manufacture.* *By* ALFRED E. FLETCHER, *F.C.S.*, *F.I.C.*

Reference was made to a paper read at the last Manchester meeting, giving an account of the position of the manufacture in 1861, and to papers read before the Society of Chemical Industry in 1883 and 1884 by W. Weldon, and in 1886 by E. K. Muspratt.

It was noticed that the present is the centenary year of the Leblanc process, and that until 1877 all the soda of commerce was manufactured by it.

A sketch was given of the successive improvements that have been made in the details of the process, and in the mechanical appliances devised for carrying it out. Mention was made of the Weldon and the Deacon chlorine processes; of the mechanical revolving black-ash furnace proposed by Ellison & Russell in 1853, and subsequently perfected by Stevenson & Williamson of Jarrow, and by Duffy of St. Helen's; of the finishing furnaces of Schofield and of M'Tear; of the mechanical salt-cake furnaces of Jones & Walsh, of M'Tear, of Cammack & Walker, and of Black & Larkin; of the improved hand salt-cake furnaces of Gamble, of Gaskell, Deacon, & Co., and of Wigg.

Mention was also made of the successive introduction of improvements in the chemical details of the process; of the Henderson process for recovering copper from the burnt pyrites, whereby at present 12,000 tons are annually produced; also that of Claudet for recovering silver and gold from the same source, by which means 360,000 ounces silver and 3,000 ounces gold are gained yearly. The total quantity that has been recovered by this means is over $2\frac{3}{4}$ million ounces of silver and 15,000 ounces of gold; also of the method of Carey, Gaskell & Hurter of treating their black-ash liquors by heat for the production of mono-carbonate to be used in the production of bi-carbonate of soda.

The recent rapid extension of the ammonia-soda process was then described; patented by Dyer & Hemming in 1835, successfully applied by Solway in 1866, and introduced in England in 1874 by Brunner, Mond, & Co., who now manufacture 100,000 tons nearly pure carbonate of soda annually by its means. Figures were given to show the rapid growth of this process, which in great measure is replacing that of Leblanc, but reason was given for believing that the increase cannot go on further until chlorine is produced in connection with it.

[1] Published *in extenso* in the *Chem. Soc. Trans.* Nov. 1887.

Three processes were mentioned whereby it is proposed to effect this: that of Solway for heating the residual calcium chloride with clay; that of Mond for decomposing the ammonium chloride by oxide of nickel; that of Weldon & Pechiney for decomposing magnesium chloride by heat and steam, whereby chlorine is produced; none of them were, however, commercially established. Considered as a soda process simply, it is acknowledged that the Leblanc method is now surpassed by its rival, holding its ground by virtue of its by-products, yet a strong hope was expressed that methods proposed by Carey, Gaskell & Hunter, and by Parnell & Simpson for modifications of the Leblanc process, also by Chance for a new sulphur recovery process, may so strengthen the hands of the older manufacturers as to save them from defeat.

The following table was given, showing the

Import and Export of Foreign Soda to and from Germany. Amount given in Tons.

The figures printed in *italics* indicate Exports, the *plain* figures Imports.

Year	Soda Ash	Caustic	Crystals	Bicarbonate	Total Calculated as Pure Carbonate
1872	7,513	1,331	10,977	238	12,241
1873	10,104	1,858	12,306	472	16,093
1874	15,413	3,751	11,040	404	22,638
1875	16,064	5,980	11,381	517	26,104
1876	14,412	7,831	13,253	503	27,500
1877	14,530	7,915	10,679	510	26,787
1878	14,111	9,275	9,219	452	27,474
1879	15,911	6,887	10,686	366	26,475
1880	6,061	9,373	10,053	263	20,512
1881	6,310	5,266	10,833	327	16,132
1882	5,598	6,134	7,332	297	15,251
1883	887	4,748	2,076	206	7,917
1884	*7,318*	1,973	2,037	250	*3,305*
1885	*8,962*	2,299	282	112	*6,270*
1886	*9,150*	676	*1,759*	120	*10,204*

Also a table showing the

Annual Production of Alkali, &c., in United Kingdom.

Year	Salt decomposed	Alkali, 48 per cent. Leblanc Process	Alkali, 48 per cent. Am'onia Process	Soda Crystals	Caustic Soda	Bleaching Powder [1]	Bi-carbonate of Soda	Total
1877	578,201	217,556	6,220	169,769	74,663	105,529	12,109	1,164,047
1878	568,542	196,876	11,116	170,872	84,612	105,044	11,756	1,148,818
1879	615,287	230,683	15,526	185,319	86,511	115,290	13,083	1,126,699
1880	700,016	266,093	18,800	192,926	106,384	131,606	13,539	1,429,364
1881	675,099	238,687	20,400	203,773	108,310	135,826	12,853	1,394,948
1882	679,935	233,213	39,000	180,846	116,864	135,170	14,115	1,399,143
1883	705,732	227,284	52,750	188,678	119,929	141,868	13,609	1,452,188
1884	690,502	204,072	61,480	182,567	141,639	128,651	14,576	1,423,487
1885	722,472	184,597	77,530	202,705	144,954	132,761	15,179	1,480,198
1886	713,112	165,782	85,000	182,379	153,884	136,234	15,083	1,454,465

[1] This includes Chlorate of Potash, taking 5 tons of Bleaching Powder for 1 ton of Chlorate. The amount of Chlorate now made is 7,000 tons per annum.

There are in Germany twenty-four alkali works, from which the yearly output is a quantity equivalent to 150,000 tons pure carbonate. This is against an output in 1878 of 42,000 tons.

It is doubtful, however, whether Germany can permanently maintain an export trade in soda products, since in England all the materials of that industry are cheaper and the alkali works are better situated in relation to the seaports.

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2. *On the Composition of some Coke Oven Tars of German Origin. By* Professor LUNGE.

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3. *On the Constituents of the Light Oils of Blast-Furnace Coal Tar from Gartsherrie Works. By* WATSON SMITH.

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4. *On the Utilisation of Blast-Furnace Creosote. By* ALFRED H. ALLEN, *F.C.S.*

The crude oil or tar obtained by the condensation of the gases from blast furnaces consuming bituminous coal is remarkable for the large proportion of phenoloïd bodies contained in it, the usual proportion ranging from 20 to as much as 35 per cent. The phenoloïds are now extracted from the tar on a large scale by the Eglinton Iron Company by means of caustic soda, and the residual hydrocarbons are much increased in value thereby, and become better adapted for their application for illumination (especially for use in the 'Lucigen' light), use as fuel, lubrication, &c.

The phenoloïds are recovered from their solution in caustic soda by means of an acid. They present a marked contrast to the phenols from ordinary coal-tar, and somewhat resemble the phenoloïds from wood-tar. Thus phenol and cresol are present in but small proportion, but the higher homologue phlorol, and probably creasol and guaiacol, are met with, together with other of the characteristic constituents of wood-tar creosote. By distillation a purified product is now obtained which has been named 'Neosote,' or 'new preservative,' and is likely to meet with considerable employment as an antiseptic. Experiments have proved that, as an antiseptic, the purified creosote from blast-furnace tar is quite equal to carbolic acid; but the sale of a very crude product of the same origin, under the name of 'crude carbolic acid,' as now practised, is reprehensible and misleading.

The phenoloïds of shale tar are of similar general character to those from blast furnace tar, but their purification presents greater difficulties.

The purified product, or neosote, from blast furnace tar, distils almost wholly between 200° and 225° C.; whereas many of the crude phenoloïds from coke-oven tar and other sources, now being illicitly disposed of as crude carbolic acid, give little or no distillate below 220°, and distil in great part above 300°. Calvert's 'No. 5 carbolic acid,' which represents a fair quality of coal tar acids, distils chiefly between 200° and 220° C.

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5. *A new Apparatus for Condensing Gases by Contact with Liquids. By* Professor LUNGE.

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6. *The Extent to which Calico Printing and the Tinctorial Arts have been affected by the Introduction of Modern Colours.*[1] *By* CHARLES O'NEILL.

The author said the first of the modern colours was M. Perkin's aniline mauve, which was discovered and applied in the year 1856. It was two or three years afterwards—in April, 1859—that the next modern colour, magenta or fuchsia, made its appearance. The tide rose slowly in 1860 with purples, blues, and violets, and gained every year in force and volume, until the flood had now risen to such a height, that one who would like to keep up with it stood astonished and dismayed

[1] Printed *in extenso* in the *Journal of the Society of Chemical Industry*, Nov. 1887.

at its extent, and well-nigh confounded by the prospect before him. Nor were there any signs that we had got to the high-water mark, for month after month chemists and colour manufacturers were patenting new colours or new processes, in such numbers that only a specialist of specialists could pretend to follow or appreciate the work that was being done. After reviewing the progress which had been made in the invention of printing colours of late years, the author said that in 1856 the two most important colouring matters were indigo and madder. Neither of those colours could be directly printed on calico. Indigo in the form of China blue was printed on it, to be subsequently fixed by a process analogous to dyeing, but it was not an important branch of the indigo styles. All attempts to obtain an extract of madder fit for printing had failed, and it was not until about ten years afterwards that an extract of madder came into the market, and for the first time the printer was enabled to produce by direct application upon the cloth various colours yielded by madder. The madder styles of 1856 were of great excellence, and, as produced by the best houses, quite as good, or better, than pure alizarine styles were now, not that alizarine could not be made to yield as good work as madder did; the present conditions of the trade with regard to price, however, were unfavourable to the highest excellence in that class of prints. He pointed out that if artificial alizarine had not come up there could not have been the extensive productions of many-coloured fast cretonne styles which had been the characteristic of the trade for several years past. The introduction of this most important and valuable of the modern colours had had the effect of cheapening the price of the best kinds of calico prints. By best he meant those of the most durable colours used for personal wear, and so far it was a boon to the purchaser; but how far it had benefited the calico-printers was another question. It would appear that the greater facility of producing passable colours had greatly increased the production. The same works and machinery could with these and other modern colours turn out from 50 to 70 per cent. more printed calico than could have been done in the old madder-dyeing days. Increased production without a corresponding increase in demand had, of course, led to a gradual lowering of prices, until profits were cut down to a very low margin. He thought it might be held that the colour mixing made easy by the introduction of modern colours had much to do with the unremunerative condition of calico-printing. Comparing work done thirty-four years ago with that which was produced now, he thought there had been no great change in results as far as regarded the quality of the work. There had been a lessening of the cost of colour and a lessening of the labour of the colour mixer, and undoubtedly some colours now were brighter than then, but there was not much in that. As to fastness of colour, except as regarded reds, there had been no gain, perhaps even a loss. None of the modern colours, except alizarine and its allied blue and orange derivatives, could be said to be fast colours upon cotton in the sense that madder or indigo were fast, but, at the same time, many of them were fast enough for the purpose to which they were applied. The idea that all new dyes were bad dyes and that in the old times there were no loose colours was not warrantable. The truth was that with the ancient dyes as with the modern dyes there was plenty of loose bad dyeing. If the wholesale condemnation of modern colours were correct, these dyes must have fallen into disuse long ago. Whichever might be the true state of the case with regard to cotton, he considered that the introduction of modern colours in the dyeing of fancy silk and woollen styles had been a great advantage.

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7. *Exhibition of a new class of Colouring Matters.* *By* Dr. C. A. Martius.

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8. *The Chemistry of the Cotton Fibre.* *By* F. H. Bowman, *D.Sc., F.R.S.E., F.C.S., F.L.S.*

After referring to the importance of the subject and the necessity for further information in regard to the principles which underlie our industrial processes it

was pointed out that our investigations in regard to the cotton fibre must embrace its mechanical and chemical structure.

After speaking briefly of the mechanical structure it was shown that cotton in common with all vegetable substances has for its base cellulose. This substance was formerly supposed, so far as cotton is concerned, to be a definite and fixed compound having the composition indicated by the formula $C_6H_{10}O_5$. The results of the analysis of various kinds of cotton were then referred to, and it was shown that there is strong reason to suppose that the fibre as met with under ordinary circumstances is really composed of a series of bodies more or less corresponding to this formula but differing from it in regard to the arrangement of the hydrogen and oxygen atoms within the molecule and thus constituting a series of celluloses which have a distinct differentiation rather than one single composition. It was also noticed that, having due regard to the atomicity of the constituents of the typical cellulose molecule it is impossible to conceive that the hydrogen and oxygen atoms are arranged in the molecule, in the same atomic combination as water, although water is always associated with the fibre to the extent of 5 to 7 per cent. and hence the conclusion is drawn that this water of hydration is not an essential constituent of the cellulose molecule. After summing up our knowledge of the general chemical characters of the cotton cellulose reference was made to the hydration and de-hydration changes of which cellulose is capable as exhibited in recent researches on this subject, and special mention was made of oxycellulose and its reactions. The behaviour of this body and its allies as distinguished from cellulose and the reactions of the latter when treated with acids and alkalis were then discussed, and the light which these throw on the probable constitution of cotton was pointed out.

Considerable stress was then laid upon the fact that the cotton fibre always contains mineral matter to the extent of 1 per cent. as an integral part of its structure, and the importance of this as a factor in the chemical reactions of the cotton fibre was insisted upon, and various researches which throw evidence upon this point were mentioned. Finally, notice was taken of the invaluable presence of oils, fats, and waxes along with cotton fibre, and the necessity for due consideration of this fact in the methods employed in manipulating the fibre for technical purposes.

SUB-SECTION B.—ORGANIC CHEMISTRY.

1. *Second Report of the Committee for investigating Isomeric Naphthalene Derivatives.*—See Reports, p. 231.

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2. *Isomeric Change in the Phenol Series.* *By* A. R. LING.

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3. *The Constitution and Relationship of the Eurhodine and Saffranine Classes of Colouring Matters, and their Connection with other Groups of Organic Compounds.* *By* DR. O. N. WITT.

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4. *On the Constitution of Azimido-Compounds.* *By* DRS. NOELTING *and* ABT.

The azimido-compounds discovered by Hofmann, Ladenburg, and Griess, when acting with nitrous acid on ortho-diamines, have, according to Griess's opinion, the constitution represented by the following formula, $R''\begin{matrix}-\mathrm{N}\\ \mid\\ -\mathrm{N}\end{matrix}\!\!>\!\mathrm{NH}$, for example, the derivative of ortho-phenylene-diamine would be $C_6H_4\begin{matrix}\mathrm{N}\\ \mid\\ \mathrm{N}\end{matrix}\!\!>\!\mathrm{NH}$. Kékulé proposed another formula, differing from the preceding one by the manner in which the nitrogen

atoms are linked together, viz., $C_6H_4 \begin{matrix} -N-H \\ \diagdown \\ -N=N \end{matrix}$. If Kékulé's formula is the right one, the monosubstituted ortho-diamines $C_6H_4 \begin{matrix} -N \begin{matrix} -R \\ -H \end{matrix} \\ -NH_2 \end{matrix}$, should also yield azimido derivatives on being acted upon with nitrous acid, while if Griess's formula were exact, the formation of azimido derivatives from monosubstituted ortho-diamines is only explicable by admitting a rather complicated molecular transposition. We therefore prepared the mono-ethyle-ortho-toluylene-diamine, $C_6H_3 \begin{matrix} -N \begin{matrix} -C_2H^5 \\ -H \end{matrix} & 1 \\ -NH_2 & 2 \\ -CH_3 & 4 \end{matrix}$, and acted upon it with nitrous acid. By this means we obtained an azimido-compound, crystallising from alcohol in small white needles of the melting-point 147°, insoluble in alkaline solutions, whilst the ordinary azimido-toluene is soluble, and even forms a crystallised sodic compound $C_6H_3\,(CH_3) \begin{matrix} -N-Na \\ \diagdown \\ -N=N \end{matrix}$. The same ethyle-azimido-toluene was obtained by the action of ethylic iodide on the sodic azimido-toluene, and this body has therefore evidently an analogous constitution, $C_6H_3\,(CH_3) \begin{matrix} -NH \\ \diagdown \\ -N=N \end{matrix}$. In our opinion the action of nitrous acid on the three series of diamines is in the first stage the same.

Paradiamines yield diazoic salts—

$$14.\ C_6H_4 \begin{matrix} -NH_2HCl \\ -NH_2HCl \end{matrix} + HNO_2 = H_2O + C_6H_4 \begin{matrix} -N=N-Cl \\ -NH_2HCl \end{matrix}$$

and under the influence of a large excess of nitrous acid, even bidiazoic salts, $C_6H_4 \begin{matrix} -N=N-Cl \\ -N=N-Cl \end{matrix}$. Metadiamines also yield diazoic salts, but these reach upon another molecule of diamine, and form a Manchester brown—

$$13.\ C_6H_4 \begin{matrix} N=N-Cl \\ NH_2HCl \end{matrix} + C_6H_4 \begin{matrix} NH_2 \\ NH_2 \end{matrix} = C_6H_4 \begin{matrix} -N=N-C_6H_3(NH_2)_2(HCl) \\ -N=NH_2(HCl) \end{matrix}$$

In the case of ortho-diamines the diazoic group reacts on the amido group of the same molecule, and yields a kind of internal anhydride, the azimido body.

$$12.\ C_6H_4 \begin{matrix} -N=N-Cl \\ -NH_2 \end{matrix} = HCl + C_6H_4 \begin{matrix} -N=N \\ \diagup \\ -N-H \end{matrix}$$

The azimido-compounds in their constitution have some analogy with the diazo-amido-compounds, $C_6H_5-N=N-N \begin{matrix} -C_6H_5 \\ -H \end{matrix}$, but are distinguished from the latter by their stability.

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5. *On the Constitution of the Mixed Diazoamido-compounds.*[1]
By Drs. NOELTING *and* BINDER.

Griess has shown several years ago that by the action of a diazo-compound $R-N=N-Cl$ on an amine $R'NH_2$, one obtains the same diazoamido-compound as by the action of $R'-N=N-Cl$ on $R-NH_2$. It is not possible to decide from Griess's experiments whether the resulting compound has the constitution $R-N=N-N \begin{matrix} -R' \\ -H \end{matrix}$ or $R'-N=N-N \begin{matrix} -R \\ -H \end{matrix}$. Griess has proposed a $(C_6H_4)''=$

$$\begin{matrix} N & = & N & = & N & =(H_6H_4)'' \\ | & & | & & | & \\ H & & H & & H & \end{matrix}$$

which seems to us to be not probable.

[1] These two papers are published in the *Berichte der Deutschen Chemischen Gesellschaft*, and in the *Bulletin de la Société Industrielle de Mulhouse.*

We have undertaken a new study of this subject. and have especially taken into consideration the product from diabenzenechloride and paratoluidine, and from diazoparatolyl-chloride and aniline. The properties of these two compounds which, as Griess has proved before us, are in every respect identical, do not allow us to give to them a definite formula. In some reactions their behaviour corresponds to the formula of diazobenzene-paratoluide, $(C_6H_5N=N)-N\begin{smallmatrix}-H\\-C_7H_7\end{smallmatrix}$; in some others to the formula of diazoparatolyl-anilide, $(C_7H_7N=N)-N\begin{smallmatrix}-H\\-C_6H_5\end{smallmatrix}$; in others, finally, the most numerous ones, the compound has the properties of a mixture of these two derivatives. We therefore prefer to use for the compound the formula $\left.\begin{matrix}C_6H_5\\C_7H_7\end{matrix}\right\}N_3H$, which includes the two possibilities. According to our opinion we have here a new case of so-called tautomerism.

If in the amines $R-NH_2$ and $R'-NH_2$ one atom of H be substituted by an alkyle group, the diazoamido-compounds obtained by the action of $R-N=N-Cl$ and $R'-N=N-Cl$ are no longer identical but different (isomeric). The above experiments were performed in the year 1884, but had not been published *in extenso*, because they did not allow us to decide the question of the constitution of the mixed diazoamido-compounds. If we now allow ourselves to present them to this Section, the reason is that other chemists, especially Mr. Meldola, devote themselves to similar researches, and whilst we hope that our observations may contribute in some way to the resolution of this interesting question, at the same time we declare that it is not our intention to work farther on this subject.

By the action of $C_6H_5N=N-Cl$ on $C_7H_7NH_2$, and of $C_7H_7N=N-Cl$ on $C_6H_5NH_2$, one obtains $\left.\begin{matrix}C_6H_5\\C_7H_7\end{matrix}\right\}N_3H$, yellow needles of the melting point 85°, soluble in the usual solvents, except water.

The following experiments were always made with specimens obtained by the two different methods.

(*a*) Action of nascent H—produces $C_6H_5NH_2$, $C_7H_7NH.NH_2$, and simultaneously $C_7H_7NH_2$, $C_6H_5NH.NH_2$.

(*b*) Action of bromine—produces $C_7H_7N=N-Br$ and $C_6H_2Br_3NH_2$.

(*c*) Transposition with aniline—produces $C_6H_5N=N-C_6H_4NH_2$ and $C_7H_7NH_2$.

(*d*) Transposition with dimethylaniline—produces $C_7H_7N=N-C_6H_4N(CH_3)_2$ and $C_6H_5NH_2$.

(*e*) Transposition with phenol in excess—produces $C_6H_5N=N-C_6H_4(OH)$ and $C_7H_7NH_2$. Henmann and Oeconomides with the theoretical amount of phenol obtained $C_6H_5N=N-C_6H_4(OH)$, $C_7H_7N=N-C_6H_4OH$, $C_7H_7NH_2$ and $C_6H_5NH_2$.

(*f*) Splitting up with dilute H_2SO_4—produces C_6H_5OH. $C_7H_7NH_2$, and simultaneously C_7H_7OH, $C_6H_5NH_2$.

(*g*) Ethylation and decomposition with dilute H_2SO_4. The product obtained by acting in alcoholic solution with sodium and ethylic iodide is a yellow oil; with dilute sulphuric acid it splits up into C_6H_5OH and $C_7H_7N\begin{smallmatrix}-C_2H_5\\-H\end{smallmatrix}$, and simultaneously C_7H_7OH and $C_6H_5N\begin{smallmatrix}-C_2H_5\\-H\end{smallmatrix}$.

II. Action of $C_7H_7N=N-Cl$ on $C_6H_5N\begin{smallmatrix}-C_2H_5\\-H\end{smallmatrix}$, and of $C_6H_5N=N-Cl$ on $C_7H_7N\begin{smallmatrix}-C_2H_5\\-H\end{smallmatrix}$; $\left.\begin{matrix}C_6H_5\\C_7H_7\end{matrix}\right\}N_3(C_2H_5)$. The first is a yellow oil; the second forms red crystals *m. p.* 38°–39°.

(*a*) Action of the nascent H.

The first gave $C_7H_7NH.NH_2$ and $C_6H_5N\begin{smallmatrix}-C_2H_5\\-H\end{smallmatrix}$; the second $C_6H_5NH.NH_2$ and $C_7H_7N\begin{smallmatrix}-C_2H_5\\-H\end{smallmatrix}$.

(*b*) Splitting up with dilute H_2SO_4.

The first gave C_7H_7OH and $C_6H_5N\genfrac{}{}{0pt}{}{-C_2H_5}{-H}$; the other C_6H_5OH and $C_7H_7N\genfrac{}{}{0pt}{}{-C_2H^5}{-H}$.

(*c*) Transposition with phenol.

The first gave $C_7H_7N=N-C_6H_4OH$ and $C_6H_5N\genfrac{}{}{0pt}{}{-C_2H_5}{-H}$; the other $C_6H_5N=N-C_6H_4OH$ and $C_7H_7N\genfrac{}{}{0pt}{}{-C_2H_5}{-H}$.

These experiments show certainly that the two compounds are different, and different also from the product of reaction of ethylic iodide on diazoamido-toluene-benzene. It is, however, not certain if this derivative is a third isomeride or a mixture of the two described above. Mr. Meldola, on his side, has shown that there exist three different $\left.\begin{matrix} mC_6H_4(NO_2) \\ pC_6H_4(NO_2) \end{matrix}\right\} N_3(C_2H_5)$.

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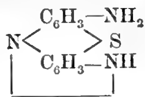
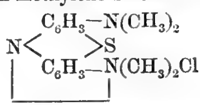
6. *On Methylene Blue and Methylene Red. By* Professor BERNTHSEN.

The author gave an account of his methylene blue and methylene red researches.[1] He reported on the artificial production of Lauth's violet [thionine] from thiodiphenylamine by nitration, reduction to diamidothiodiphenylamine, and subsequent oxidation, forwarding the violet of the constitution



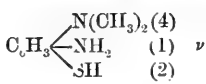
From the near relation between methylene blue and thionin the formula



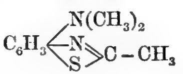
for the blue colouring matter was derived, and supported by experimental proof.

A survey was given and diagrams were presented giving a review of the details of the mentioned processes and over a number of other derivatives of thiodiphenylamine.

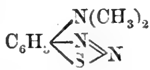
The author then passed to methylene red, a substance contained in the mother liquors of methylene blue when prepared from p-amidodimethyl-aniline, sulphuretted hydrogen, and ferric chloride in acid solution. The red, a well-defined crystalline substance, readily soluble in water, is remarkable on account of the high amount of sulphur contained in it. Proof was given that it is represented by the formula $C_8H_9N_2S_2Cl$. By reduction it produces a most interesting substance, the mercaptane of amidodimethylaniline, $C_8H_{12}N_2S$,—



a zinc salt of which can easily be isolated. This, as an ortho-compound, gives derivatives, as

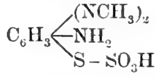


and



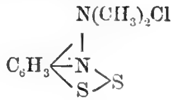
[1] Liebig's *Annalen der Chemie*, Bd. 230.

Methylene red is instantaneously destroyed by alkalis. Amongst the products of reaction an acid is found showing the formula $C_8H_{12}N_2S_2O_3$, and formed from the red by adding water and one atom of oxygen. The constitution of this acid proved to be as follows:



and it can easily be converted into the mercaptane and *vice versâ.*

From these and other facts not yet published the author concludes that methylene red is represented by the formula



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7. *On some Xenoene or Diphenyl Products and Reactions.* *By* Professor W. Odling, *M.A., F.R.S., and* J. E. Marsh, *B.A.*

Reference was made to Dr. Odling's paper of last year, when an analogy was presented between benzoic or phenyl formic acid and phenyl sulphonic acid. Benzoic acid decomposes on hydrolysis into phenoene or benzene and carbonic acid, phenyl sulphonic acid into phenoene and sulphuric acid. On fusion with potash phenyl sulphonic acid yields phenol, while benzoic acid yields a little phenol, but chiefly by a further action of carboxylation phenol formic or benzoic acid. The view that oxibenzoic acid owes its origin to a carboxylation of already formed phenol was upheld by the formation also of oxiicophthalic acid.

Some further decompositions of aromatic acids on hydrolysis were described. The hydrolysing agent is a mixture of zinc chloride and water, or stannic chloride hydrochloric acid and water. The reaction is conducted in sealed tins at a temperature of about 300°. In this way benzoic acid gives carbonic acid and phenoene, a little xenoene or dephenyl being also formed.

Phthalic acid gives carbonic acid, phenoene, and benzoic acid.

Paramido-benzoic acid gives carbonic acid and aniline.

Pure nitro-benzoic acid gives carbonic acid, and not nitro-benzene, but aniline. Nitro-benzene was also found to yield aniline and carbonic acid.

Several other aromatic acids were found to undergo a similar reaction of hydrolysis.

Ethyl benzoate treated with alcoholic zinc chloride was found to undergo decomposition into carbonic acid and probably a mixture of hydrocarbon.

An extended account was given of the action of fused potash on benzoic acid, especially as to the method employed in separating the crude acids formed. The method depends essentially on converting the acids into compound ethers and distilling the latter under reduced pressure. In this way besides the two xenyl formic acids obtained by Barth and Schuder a new xenylene diformic acid or diphenyl dicarbonic acid was obtained.

Certain derivatives of the hydrocarbon xenoene or diphenyl were considered and described.

Acetonenone, previously obtained by Adam, melting at 120 – 121° is found to yield on oxidation paraxenyl formic acid, and is therefore itself a para compound.

Benzonenone is obtained by the action of benzoyl chloride with aluminium chloride on xenoene in petroleum spirit. It is the phenyl xenyl katom, and it melts at 99° C.

An account was given of a ready method of obtaining the monosulphonic acid of xenoene, namely, by dissolving the hydrocarbon in chloroform and adding a slight excess of sulphuryl chlorhydrate.

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8. *On the Rate of Velocity of Formation of Acetic Ether.* *By* Professor Menschutkin.

MONDAY, SEPTEMBER 5.

The following Papers were read:—

1. *The Relation of Geometrical Structure to Chemical Properties. By* Professor WISLICENUS.

2. *Note on Valency, especially as defined by Helmholtz. By* Professor ARMSTRONG, *F.R.S.*

3. *The Solubility of Isomeric Organic Compounds. By* Professor CARNELLEY, *D.Sc., and* Dr. A. THOMSON.

1. *For any series of isomeric organic compounds the order of solubility is the same as the order of fusibility*, i.e. the most fusible compound is also the most soluble. (Cf. Carnelley, 'Phil. Mag.' (5) 13, 180; also Tilden, 'Journ. Chem. Soc.' 45, 266).

This is shown to hold true in a very large number of cases, whilst there are very few exceptions, and those of a doubtful character.

2. *The order of solubility of two or more isomeric compounds is independent of the nature of the solvent.* This has been experimentally proved, more particularly in the case of meta- and para-nitraniline, the solubility of each of which in thirteen different solvents has been determined; also by a considerable number of cases taken from literature.

3. *The ratio of the solubilities of two isomers in a given solvent is constant, and is therefore independent of the nature of the solvent.* So that—

$$\frac{\text{Solubility of A in any solvent}}{\text{Solubility of B in the same solvent}} = \text{constant.}$$

This has been proved for meta- and para-nitraniline in respect of thirteen different and very varied solvents.

4. *The Melting Points of Organic Compounds in relation to their Chemical Constitution.* Part I.—*Influence of Orientation in Aromatic Compounds. By* Professor CARNELLEY, *D.Sc.*

For any series of isomeric compounds of benzene the symmetry of the orientation of the side chains has a very marked influence on the melting-point, in such a way that, *cæteris paribus, the most symmetrical orientation gives the highest melting point.* Thus, of 1,120 cases in which the law can be applied, 890 agree with the rule, though there is a high *à priori* probability against their doing so, varying from 2 : 1 to 15 : 1 in different cases.

Of the exceptions considerably more than one-half are of a doubtful character, whilst five-sixths of them depend on one authority only.

Further, as regards *all* benzene isomers the order of infusibility, much more frequently than not, follows the order of symmetry of orientation, though the *à priori* probability against their doing so is a very high one.

5. *Alcohol and Water Combinations. By* Professor MENDELÉEF.

6. *On the Constitution of Atropine.*[1] *By* Professor LADENBURG.

By the researches of Kraut and Lossen we have learnt that the alkaloid of the belladonna atropine $C_{17}H_{23}NO_3$ is decomposed by hydrochloric acid or hydrate of baryta in tropine $C_8H_{15}NO$ and tropic acid $C_9H_{10}O_3$.

[1] *Ann. Chem.* 217, 74; *Ber.* 16, 1408; and *Ber.* 20, 1647.

$$C_{17}H_{23}NO_3 + H_2O = C_8H_{15}NO + C_9H_{10}O_3.$$

In respect to the constitution of the last all doubts have been destroyed by a research which I have made in connection with my assistant, Dr. Rügheimer. We arrived to the first synthesis of this acid, and have fixed its formula to

$$C_6H_5CH{<}^{CH_2OH}_{COOH}.$$

The nature of the basic component of the atropine had been quite obscure before my researches. I could demonstrate in first line that tropine is not only a base but also an alcohol, that it belongs to a class of compounds which I name alkines. I proved this by forming etherical derivatives, the tropeïnes. These compounds are produced by treating tropine with organic, especially aromatic, acids in presence of dilute hydrochloric acid. In this manner atropine itself is formed by the action of tropine on tropic and hydrochloric acid. In treating tropine by oxytoluic acid in presence of hydrochloric acid homatropine is formed, a base very similar in its physiological action to atropine, and of great value in the therapeutics of the eye. Therefore we can suppose a group of hydroxyl in tropine and write its formula $C_8H_{14}(OH)N$.

The alcoholic nature of tropine comes still more to evidence in studying the action of jodhydric acid and amorphous phosphorus on it. Diiodide of tropine $C_8H_{15}NI_2$ is formed. This substance comports itself like the jodhydrate of a base containing iodine. The reaction is quite analogous to that which with nevrine takes place—

$$C_5H_{13}NO + 2HI = C_5H_{12}N_1IHI + H_2O$$
$$C_8H_{15}NO + 2HI = C_8H_{14}N_1IHI + H_2O.$$

The iodide of tropine treated with zinc-dust and chlorhydric acid is reduced and yields the hydrochlorate of a tertiaric base, having the formula $C_8H_{15}N$, which I name hydrotropidine. It boils at 168° and is characterised by very fine salts.

The hydrochlorate of this base distilled in a current of hydrochloric acid yields chlorine of methyl and is transformed in the hydrochloride of a new base, which I call norhydrotropidine, the composition of which is expressed by the formula $C_7H_{13}N$. We have $C_8H_{15}NHCl + HCl = C_7H_{13}NHCl + CH_3Cl$. This base is crystalline, melts at 61°, and boils at 161°. It is a secondary base, which by the action of nitrous acid is transformed into a nitrous amine melting at 117°. The hydrochlorate of this base is not deliquescent, and yields, by its distillation with zinc-dust, hydrogene and a tertiaric base, which already by its smell is recognised to appertain to the pyridine series. After purification I could prove the identity of this base with α ethylpyridine, which I have prepared synthetically in heating pyridine with the iodide of ethyl. So that we can write the equation

$$(C_7H_{13}NHCl)_2 + Zn = ZnCl_2 + (C_7H_9N)_2 + H_{10}.$$

We may conclude by these facts that norhydrotropidine is tetrahydro α ethylpyridine and hydrotropidine ν methyl α ethyltetrahydropyridine

$$C_5H_7(C_2H_5{}^{\alpha})NC^{\gamma}H_3.$$

Tropine itself obtains the formula

$$C_5H_7(C_2H_4{}^{\alpha}OH)NCH_3;$$

and atropine

$$C_5H_7(C_2H_4OCO\diagdown\underset{\substack{|\\ C_6H_5}}{CH}\diagup CH_2OH)NCH_3$$

It is not impossible that the hydroxyl substitutes one atom of hydrogen in the pyridine group, but I think it not so probable as the supposition I made above.

The synthesis of tropine must start from α ethylpyridine, and I made several experiments in this direction, but till now without success.

7. *The Reduction-products of the Nitro-paraffins and Alkyl Nitrites.* *By* Professor Dunstan *and* T. S. Dymond.

The reduction-products of ethyl nitrite have been investigated by Geuther, who used zinc and diluted sulphuric acid as the reducing agent, and found that the reaction was represented by the equation $C_2H_5NO_2 + 2H_2 = C_2H_5OH + NH_3$. A trace of ethylamine was also formed, but this has been attributed to impurity in the ethyl nitrite. Emil Kopp used ammonium sulphide as the reducing agent, and also obtained alcohol and ammonia, but apparently no ethylamine.

The authors have studied the reduction of ethyl nitrite, using ferrous hydroxide as the reducing agent, and have obtained an entirely different result. More than two-thirds of the nitrogen of the ethyl nitrite is liberated in the form of gas, either nitrous oxide or nitrogen; the remainder appears as ammonia and a trace of ethylamine. If potassium hydroxide is mixed with the ferrous compound a considerable quantity of potassium hyponitrite is formed. It is also probable that ethyl hyponitrite, a compound that has not yet been prepared, may be formed as an intermediate compound. The authors are further investigating the change with the object of isolating this compound and of discovering the mode of formation of the ethylamine. They have previously shown ('Journal of the Chemical Society,' August 1887) that sodium nitrite is reduced by ferrous hydroxide to nitrogen and ammonia, sodium hyponitrite being formed as an intermediate product.

The reduction-products of the nitro-paraffins have been studied by Victor Meyer. Nitroethane was reduced, by iron and acetic acid, to ethylamine without the formation of any ammonia. $C_2H_5NO_2 + 3H_2 = C_2H_5NH_2 + 2H_2O$. When ferrous hydroxide is used the authors find that much ethylamine is produced, a little ammonia, and a substance having a strong alliaceous smell, which is being further investigated. No gaseous product is formed. Nitromethane yields, under the same conditions, methylamine, a little ammonia, and a substance having an alliaceous smell. Nitro-benzene is entirely converted into aniline. The authors intend to further investigate these reactions, which they think are likely to throw new light on the constitution of inorganic and organic nitro-compounds.

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8. *On the Second Monobromo-benzene.* *By* Professor Fittica.

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9. *Saccharine, the new Sweet Product from Coal-tar.* *By* Dr. Fahlberg.

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10. *On a Partial Separation of the Constituents of a Solution during Expansion by Rise of Temperature.* *By* Professor J. W. Mallet, *F.R.S.*

It was observed in regard to a thermometer containing coloured alcohol, the colour due probably to cochineal, that on several occasions when rise of temperature occurred somewhat gradually in the room after rather severely cold weather the upper part of the column of liquid was colourless or nearly so, while no deposition of any solid colouring matter could be seen in the bulb or the lower part of the tube. Colourless alcohol had apparently separated itself by expansion from a still perfect solution left behind.

This led to making some experiments with solutions, partly aqueous, partly alcoholic, of several colloid substances, such as starch, tannin, caramel, albumen, and gelatine. Each solution was placed in a flask of about half a litre capacity, which was brought to near 0° C. by being surrounded with ice, filled to the mouth with the solution at this temperature, and closed by a cork traversed by a glass tube of small but not capillary bore (about 4 mm. interior diameter), 15 or 20 centimètres long, and having a glass stopcock in the middle of its length. The ice having been removed the temperature of the flask and its contents was allowed to rise gradually in a warm room until the head of the column of liquid in the tube, originally one or two centimètres below the stopcock, had reached to about as

far above it. The stopcock was then cautiously closed and the small portion of liquid above it, removed by means of a capillary pipette, was submitted to appropriate tests for the substance in solution in the contents of the body of the flask. In contrast with a sample of equal volume taken from the flask itself, the portion which had been slowly driven up by expansion was found to contain a diminished amount of material in solution, often a very notably diminished amount, and in two or three instances practically none.

All the solutions tried were filtered beforehand through four thicknesses of fine close filtering-paper so as to remove suspended particles of solid matter. No film consisting of, or rich in, the material dissolved in the bulk of the liquid could be detected on the inner surface of the tube in its upper part, so that the separation could not well be attributed to surface adhesion.

The extent of exposure to the air on the small cross-section of the tube would hardly allow of an explanation being found in chemical change of the dissolved material.

The term apantlesis (ἀπάντλησις) might be used to signify a draining away of some of the molecules of the solvent undergoing expansion from amongst those of the colloid solid in solution. Such draining away would seem to connect itself on to change in the opposite direction, but leading to the same result, when the colloid begins to separate out by gelatinising on cooling.

The conditions which seemed most to influence the production and the distinctness of the phenomenon were—first, the proportion of the colloid solid in solution; and second, the time occupied in the rise of temperature of the liquid. In regard to each of these conditions there appeared to be a certain point at which the separation was most notable, above or below which it became gradually less distinct, and sufficiently removed from which it was not observable at all.

SUB-SECTION B.—CHEMICAL SCIENCE.

1. *The Chemical Structure of some Natural Silicates.* *By* F. W. CLARKE.

The common impression that the silicates are exceedingly complicated is probably erroneous. The complexity is apparent, not real. Isomorphous mixtures exist, impurities occur, and inexact analyses are published; and these causes account for the prevalent belief. The natural silicates are generated under conditions which preclude great complexity, such as conditions of high temperature, &c. They are stable, and therefore presumably simple, and they are moreover few in number. Only five or six hundred are known as natural minerals; whereas, if they were as complicated as many organic bodies, thousands should be commonly found.

Eliminating the errors due to isomorphism, impurity of material, &c., it is found that all double silicates may be represented as substitution derivatives of normal silicates. The formulæ so developed well represent the natural associations and alterations of mineral species, particularly among the aluminum salts. Possibly the same generalisation may be extended beyond the silicates, so as to include all double salts, although the double acetates, formates, haloids, &c., offer difficulties.

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2. *Apparatus for Measuring the Volume of Gas evolved in various Chemical Actions, with or without the Application of Heat, with proposed Extension to Organic Analysis, and to the Continuous Determination of Abnormal Vapour Densities.* *By* F. W. WATKIN, *M.A.*

The apparatus consists of generating tubes, flasks, and U measuring tubes, in direct communication with the generating tubes; the measuring tubes contain water, and readings are taken with the water at the same level in the two

branches of each U tube, so that the readings are all at the barometric pressure. To correct for change of temperature, if at the time of making the final readings the temperature of the room should not be the same as at the time of the initial readings, by the side of the generating tube flasks, measuring tubes, &c., an exactly similar piece of apparatus is placed, consisting of tube, flasks, measuring tubes, &c., and having approximately the same volume as the original piece of apparatus.

The process employed was shown at the meeting of the Association, and the proposed method of application to organic analysis, by which CO_2, H_2O, and N may be concurrently determined, and to abnormal vapour densities was explained with the assistance of diagrams.

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3. *On the Teaching of Chemistry.* *By* M. M. Pattison Muir, *M.A.*[1]

Why does chemistry progress so slowly in this country? One of the many answers that may be given to this question is: because chemistry is so little taught. Although many classes are conducted nominally in chemistry, yet very little of what is taught is really chemistry. Sometimes catalogues of so-called facts are taught; sometimes generalisations and definitions detached from the facts on which they rest are placed before the student. But chemistry is really a branch of natural science.

When the student is expected to read, and if possible to remember, statements of detached facts about each of the elements and its compounds, such statements become false to him, because they conceal the really important facts regarding the connexions between changes of composition and changes of properties which form the subject-matter of chemistry. A fatal distinction is too often drawn between the facts on which chemical science rests, and reasoning and generalising on these facts.

Chemistry deals with a certain class of natural occurrences, and by studying these it seeks to rise through empirical generalisations to natural laws. The business of the teacher is to make his pupil understand the methods of chemistry, by putting before him well selected and typical chemical facts, in order that he may learn the meaning and importance of the subject he is studying, and thus may become imbued with the true scientific spirit which finds its only legitimate outlet in the continual investigation of natural occurrences.

Four things are to be especially kept in view in teaching chemistry; (1) to teach so that the student shall acquire real knowledge; (2) to carefully select the facts and the reasoning set before the student; (3) to impress the learner with the importance and value of what he is learning as a part of that orderly and methodised study of nature which we call science; (4) to teach without fear of the examiner.

Real chemical knowledge can only be gained by connecting the experimental work done in the laboratory with chemical reasoning and with the principles of the science. To do this it is necessary that a well arranged and properly graduated system of practical chemistry should take the place of the present routine of qualitative and quantitative analysis. Analysis is one of the instruments of chemistry, but chemistry is much more than analysis. The work done in the laboratory must be in direct and constant connexion with the lecture-work and the reading of the student; it must also be progressive; and it must be arranged so that as the experiments become more difficult the reasoning becomes more close and accurate. Such a course of practical chemistry can be arranged without complicated laboratory appliances. The outline of such a course is then sketched in the paper.

The basis on which chemical facts should be selected is found in the treatment of the elements and their compounds in groups, and not, as is generally done at present, as isolated bodies. In this way the student gains some grasp of the subject he is studying, and he is not obliged to ask why he should burden his memory

[1] Published in full in *Nature*, vol. xxxvi. p. 536.

with the properties of each one of a long list of bodies when the remembrance of these properties does not help him to a knowledge of chemistry.

The importance and value of chemistry, as of any branch of natural science, can only be made clear by the teacher and the learner working together at the elucidation of some of the simpler problems of the science; but this can be done well only when the teacher is possessed of a clear and vivid imagination, and when he thoroughly believes in the subject he is teaching.

Finally the examiner must be forgotten. The examiner is too often himself unacquainted with the subject in which he examines. Much more care should be exercised in choosing those who are to examine, especially those who are to examine the results of the chemical teaching given in schools.

The outcome of all scientific teaching must be to train men to become competent to investigate nature for themselves. But unless the men are properly trained, and are taught by the examples, more than by the precepts, of their teachers what true scientific research is, they will only add a few more facts to that vast gathering which is so often but so falsely called chemistry, and they will persuade themselves that in doing this they are advancing the scientific study of nature.

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4. *Suggested Amendment of Chemical Nomenclature.* *By* Professor A. SMITHELLS, *B.Sc.*

The object aimed at is to simplify chemical nomenclature by introducing a general term to indicate the degrees of capacity which chemical compounds of acid or basic character possess of entering into reaction with bases or acids to form salts or salt-like bodies. The present system of terminology is contradictory, and offers great difficulties to beginners. The following are some of the difficulties met with:—

a. An acid containing one atom of hydrogen replaceable by a metal to form a salt is called monobasic, yet compounds like CH_4 and $NaHCO_3$ fulfilling the above conditions are not acids. The term basic is used in the following contradictory senses: Na_2O is a basic compound (oxide), HNO_3 is a monobasic compound (acid), $BiONO_3$ is a basic compound (salt). Phenol is not called a monobasic alcohol, although it forms C_6H_5ONa.

b. The term acid is also used in contradictory senses: HNO_3 is an acid, $CuSO_4$ is acid (to test paper), $NaHCO_3$ is an acid salt, $NaHO$ is a monacid base. Two of these compounds have an acid reaction, two an alkaline or basic reaction.

c. The nomenclature of alcohols is unsatisfactory. The term monatomic is properly applied to a molecule (like that of zinc) which contains only one atom. To apply the term hexatomic to molecules of sulphur and of mannitol is confusing. The term monacid is equally inapplicable, as in the case of phenol which is not a base-like compound, and should rather be called monobasic. The term monhydric literally implies one atom of replaceable hydrogen or hydroxyl, yet glycollic acid is called monhydric. Na_2HPO_4 is monhydric in a different sense. HCl is hydric chloride, H_3PO_3 is trihydric but only dibasic.

d. Anhydrides are not named like acids. SO_3 is not called dibasic, though it unites with BaO to form $BaSO_4$; nor are ethers spoken of as diacid oxides or bases.

e. There is no good term to distinguish between such bodies as $PbCO_3,Pb(OH)_2$, and $PbCO_3,2Pb(OH)_2$.

In view of these and other difficulties it is proposed to use the word *voracity* to indicate the property possessed by compounds of acid or basic function of entering into reaction respectively with bases or acids. From this we get the words *monovoric, divoric, trivoric, tetravoric,* &c. Thus an acid or body of acid function which reacts with one molecule of caustic potash to form a salt is a monovoric acid, whilst on the other hand a base or base-like body capable of entering into reaction with one molecule of hydrochloric acid to form a salt is a monovoric base.

The following are some examples of the use of the terms:—

Glycerol is a trivoric alcohol.
Resorcinol is a divoric phenol.
Orthophosphoric acid is a trivoric acid.
Ethyl ether is a divoric base.
Mercuric oxide is a divoric base.
$HgO,Hg(NO_3)_2$ is divorobasic mercuric nitrate.
$2HgO,Hg(NO_3)_2$ is tetravorobasic mercuric nitrate.
SO_3 is a divoric anhydride.

In the case of bodies of double function such as ZnO, which with HCl gives $ZnCl_2$, and with $KHOK_2ZnO_3$, it is proposed to use the term *amphid.* Thus Al_2O_3 is a hexavoric amphid oxide giving Al_2Cl_6 and $2Al(OK)_3$. C_2H_5OH is amphid, giving C_2H_5Cl and C_2H_5OK.

Some confusion exists at present in expressing the readiness with which bodies enter into chemical action. We say, for example, 'strong sulphuric acid is a strong acid,' using strong in the first place to express concentration, in the second to denote chemical effect. The term *avid* is suggested as an adjective for general use in this sense. We should thus call KHO a very avid monovoric base.

With reference to the terms already in use the following proposals are made:—

Monad or monovalent, &c., to be retained for elements and radicals.

Monatomic, &c., to be retained to denote the total number of atoms in a molecule.

Acid, to be retained for bodies of acid function.

Base, to be retained for bodies of basic function.

Monhydric, &c., to be abolished.

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5. *A Study of the Action of Nitric Acid on Benzene.* *By* Professor Lothar Meyer.

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6. *On Professor Ramsay's Method of determining Specific Volumes.* *By* Professor Lothar Meyer.

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7. *The Reduction of Nitrates by Micro-organisms.* *By* R. Warington, *F.R.S.*

The reduction of nitrates to nitrogen gas in sewage, and waters containing sewage, appears to have been first observed by Angus Smith in 1867; he afterwards published many experiments on the subject in the Reports to the Local Government Board of 1882 and 1884.

The reduction of nitrates to nitrogen in soil was first observed by Schloesing in 1873. My own experiments on this branch of the subject were made in 1880.

That the reduction of nitrates in sewage is due to the action of micro-organisms was first shown by Meusel in 1875. Dehérain and Maquenne in 1883 proved that reduction in soil was brought about by similar agency.

The conditions of reduction are a medium and temperature suitable for the growth of the organism, the presence of oxidisable organic matter, and the absence of a great excess of air. The products of the reduction of nitrates are either nitrites, nitric oxide, nitrous oxide, or nitrogen gas. The difference in the product is determined partly by the conditions in which the organism acts, and partly by the specific character of the organism. Up to the last two years experiments have been generally made with natural mixtures of organisms. Working with such mixtures it is easy to conclude that the result depends on the composition and condition of the medium; such conclusions have to be considerably modified when we become acquainted with the results yielded by individual species of bacteria.

In 1886 Gayon and Dupetit published a splendid research on the reducing powers of certain individual species of bacteria. Reduction to nitrites they find

to be a usual property of bacteria; many, however, reduce only to nitrites, while others reduce to nitrogen gas. One of the latter class of bacteria produces much nitrous oxide if asparagine be present in the solution.

My own results were obtained in the present summer, and are as yet incomplete. About twenty organisms have been examined, most of which have been kindly supplied in pure cultures by Dr. E. Klein, F.R.S. Out of these twenty about thirteen readily reduce nitrates to nitrites, even at 20°; two organisms only reduce in very nourishing liquids or at high temperatures; five organisms do not reduce nitrates, even when air is nearly excluded. A considerable number, if not all, of the reducing organisms produce nitrites, but no gas.

It appears thus that the property of reduction, and the extent to which reduction is carried, depends largely on the specific nature of the organism. When the chemical properties of individual species of bacteria have been further studied, we shall be able to classify them according to their behaviour, and be much aided in the discrimination and identification of species.

8. *A new Method for Determining Micro-organisms in Air.* *By* Professor Carnelley *and* Thos. Wilson.

This is a modification of Hesse's well-known process. It consists essentially in the substitution of a flat-bottomed conical flask for a Hesse's tube. Its chief advantages are:—(1) Much smaller cost of flask and fittings as compared with Hesse's tubes; (2) very much fewer breakages during sterilisation; (3) great economy in jelly; (4) freedom from leakage during sterilisation; (5) results not vitiated by aerial currents.

TUESDAY, SEPTEMBER 6.

The following Report and Papers were read:—

1. *Report of the Committee for further investigating the Action of the Silent Discharge of Electricity on Oxygen and other Gases.*—See Reports, p. 42.

2. *The Absorption Spectra of Rare Earths.* *By* G. H. Bailey, *D.Sc., Ph.D.*

This paper is an examination of the conditions of observation of absorption spectra with special reference to the recent announcement of the twenty new elements of Krüss and Nilson. The author finds that the strengths of the absorption bands do not diminish equally in all parts of the spectrum when the liquid is diluted.

The presence of nitric acid also effects not only a displacement of the bands, but also an alteration in their relative intensity. It is further pointed out that a record of the strength of the bands in mixtures containing, in some cases, large quantities of samarium and erbium, and in others none, cannot be used as a means of comparison and deductions drawn from variations of intensity. Whilst acknowledging that with due allowance for such factors some assistance may be gained towards the course of fractionation, the author considers the announcement of new elements quite premature, and only calculated to throw further confusion into this already difficult field of work.

3. *The Absorption Spectra of the Haloid Salts of Didymium.* *By* G. H. Bailey, *D.Sc., Ph.D.*

Bunsen has described certain variations that occur in the absorption spectra given by crystals of the didymium salts. In this paper are detailed the variations produced in the absorption spectra of crystals of didymium salts when examined

in polarised light. A comparison of the chloride, bromide, and iodide of didymium has also been made, from which it appears that in the bromide the bands are situated 5λ further towards the red end of the spectrum than in the chloride, whilst the displacement for the iodide is 14λ towards the violet. In the *solution* of the chloride (or nitrate) the bands have almost the same position as in the crystals of the iodide, whilst the addition of nitric acid causes a displacement of 12λ towards the red. It is proposed to determine how far this displacement of bands is due to the dispersion equivalent of the menstruum, and whether it gives evidence of dissociation in the liquid.

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4. *On Solution. By* William Durham, *F.R.S.E.*

The object of this paper is to show that thermo-chemical results accumulated of late years entirely support the theory of solution which the author brought forward in a paper read before the Royal Society of Edinburgh in January 1878, and developed in subsequent papers.[1]

That theory may be briefly described as follows. Solution is due to the chemical affinity of the elements of the substance dissolved for the elements of the solvent. For instance, common salt, Na_2Cl_2, dissolves in water because of the affinity of Na_2 for O and of Cl_2 for H_2. Further, chemical affinity is not in all cases exhausted when definite compounds are formed, but sufficient remains to form what may be called 'solution compounds.'

In support of this view it is pointed out that in all chlorides, bromides, iodides, sulphates, and nitrates for which data are available the heat of solution *varies directly*—

(1) As the heat of combination of the positive element of the salt with O in water varies.

(2) As the heat of combination of the negative element of the salt with H varies. And *inversely*—

(3) As the heat of combination of the positive and negative elements of the salt varies. Examples are given, such as the following:—

Compound	Heat of Combination	Difference	Heat of Solution	Difference
$[Mg,Cl^2]$	151010		35920	
$[Mg,O,Aq]$	148960	2050		
$[Ca,Cl^2]$	169820		17410	+18510
$[Ca,OAq]$	149260	20560		
		−18510		+18510
$[Na,Cl]$	97690		−1180	
$[H,Cl,Aq]$	39315	58375		
$[Na,Br]$	85770		−190	−990
$[H,Br,Aq]$	28380	57390		
		+985		−990

[1] *Proceedings of the Royal Society of Edinburgh*, Jan. 21, 1878; May 17, 1886; Jan. 17, 1887; July 18, 1887. *Nature*, vol. xxxiii. p. 615; vol. xxxiv. p. 263; vol. xxxvi. p. 316.

The author further shows that if we take two salts, say chlorides, in one of which the heat of combination is greater than in the other, we find that the difference appears in the increased heat of solution of the latter, modified by the difference of affinities of the metals for O; as for example:—

Difference of Heats of Combination		Difference of Heats of Solution
$[K^2,Cl^2] - [Li^2,Cl^2]$	$=23600$	$[Li^2,Cl^2]-[K^2,Cl^2]=25760$
$[Li^2,O,Aq]-[K^2,O,Aq]$	1960	
	25560	25760

Also in comparing chlorides with bromides it is found that the excess of heat of combination of the two salts over that of their respective acids varies inversely as the heat of solution of the two salts; thus—

Difference of Heats of Combination		Difference of Heats of Solution
$[Ba,Cl^2]-[H^2,Cl^2,Aq]$	116110	$[Ba,Br^2]$ $[Ba,Cl^2]$ 2910
$[Ba,Br^2]-[H^2,Br^2,Aq]$	113200	
	2910	2910

Finally, by taking pairs of any salts every consideration but heats of combination on the one side and heats of solution on the other can be eliminated; and it is evident the heats of solution just vary inversely with the heats of combination; as, for instance—

Difference of Heats of Combination		Difference of Heats of Solution
$[Mg,S,O^4]-[Mg,Cl^2]$	151300	-15640
$[Zn,S,O^4]-[Zn,Cl^2]$	132860	$+\ 2800$
	$+18440$	-18440

In considering how the absolute amount of heat of solution arises, the author shows that it seems to be due to a balancing of affinities among the constituent elements, and that when, for instance, $[M,Cl^2]-\{[M,OAq]+\text{Neutr.}\}$ is equal to $[H^2,Cl^2,Aq]-[H^2,O]$ there is no heat of solution, and the salt is insoluble. Several examples of chlorides and other salts are given. It would appear also that when an oxide is neutralised by an acid solution and the salt remains in solution the operation is not complete; either the oxide and the acid are not completely decomposed when we have positive heat of solution, or, on the other hand, the salt and water resulting from the double decomposition are not completely formed when we have negative heat of solution. When both parts are complete we have insolubility. Several examples are given to show this. It is also pointed out in this paper that in the case of the sulphates when the heat of combination of the oxide with sulphuric anhydride is equal to the heat of combination of the metal with sulphur there is no solubility, but when the former is less than the latter, solution immediately appears; thus—

$[SrO,SO^3]=99220$	$[Sr,S]=99220$	salt insoluble
$[CaO,SO^3]=84200$	$[Ca,S]=92000$	salt slightly soluble
$[MgO,SO^3]=53070$	$[Mg,S]=79660$	salt very soluble

The author finally draws attention to the fact that solution is probably a periodic function of the elements.

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5. *On the Thermal Phenomena of Neutralisation and their bearing on the Nature of Solution.*[1] *By* W. W. J. NICOL, *M.A., D.Sc., F.R.S.E.*

The author examines the thermal equation

$$M,R,Aq-M',R,Aq=M,R',Aq-M',R',Aq,$$

expressing the general relationship existing between the heats of formation of

[1] *Chemical News*, 1887.

various salts in dilute aqueous solutions. The pressure of water vapour from salt solutions seems to support the relation

$$MR,Aq - M'R,Aq = MR',Aq - M'R',Aq ;$$

and if this be so, then

$$M,R - M',R = M,R' - M',R',$$

a relation which is shown to be in accordance with the probabilities of the case.

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6. *On a probable Manifestation of Chemical Attraction as a Mechanical Stress. By* Professor JOHN W. LANGLEY.

Attention was first called by Gladstone and Tribe, in 'Proc. Roy. Soc.' xix. p. 498, to the fact that a piece of copper in a solution of argentic nitrate caused the formation of a dense solution of copper nitrate containing more of the radicle NO_3 than the average solution. The present writer endeavours to explain the cause of this concentration. Experiments are given showing that a concentration of the acid radicle occurs when a salt is formed from an acid in solution, whether a metal, a metallic oxide, or a metallic hydrate be employed, and the degree of concentration for several cases is given.

Experiments with electrolysis are then detailed, using the so-called non-polarisable electrodes, and by suspending one electrode from the beam of a balance it is found that the establishment of electrolysis consists of two stages—a variable and a permanent one. During the first there is a *gain* in weight at the positive, and a *loss* at the negative electrode, which is exactly opposite to the permanent action of the cell. This action is shown to depend on the nature of the acid radicle employed, being greatest with bromine and least with acetic acid.

The action during the variable stage is then shown to be only apparently in contravention to the accepted laws of electrolysis, but, on the other hand, does denote something which is an addition to those laws. It is proved experimentally that there is an actual accumulation of acid radicle around one pole, and a diminution at the other for a *measurable* distance, and involving weighable quantities. The hypothesis is then offered that these phenomena are due to a linear attraction acting selectively between the metal and the acid radicle, and is common to the formation of a salt from an acid in solution by any process, electrical or otherwise.

Under the hypothesis, and from experimental measurements, it is shown that for a value of chemism expressed in electrical measure as a difference of potential of ·5 + volt and a quantity equal to ·69 coulomb per square centimètre, the value of the chemism of copper for SO_4 equals terrestrial gravitation at ·00124 millimètre distance.

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7. *Notes on some peculiar Voltaic Combinations. By* C. R. ALDER WRIGHT, *D.Sc., F.R.S., and* C. THOMPSON, *F.C.S.*

I. GAS-FILM ELECTRO-MOTORS.

The combinations referred to under this title constitute a class of cells in which the essential feature is that one or both of the 'plates' of the combination consists of a film or aura of gas attracted physically to, or condensed upon, the surface of an electrically conducting solid not appreciably acted upon chemically during the production of a current, but simply serving as a support for the gas-film, which does undergo chemical change. Grove's well-known oxygen-hydrogen 'gas battery,' and the various analogous combinations examined subsequently by others, are cells of this kind, where *both* plates are gas-films. We have recently examined a number of combinations intermediate in character between these and ordinary one-fluid or two-fluid cells, *one* plate only being a gas-film.

Single gas-film electro-motors, as these may be conveniently termed, may be ranged in two classes, according as the solid plate supporting the gas-film acquires the higher or lower potential. When air, oxygen, or other electro-negative gas

constitutes the film, the opposed plate being an oxidisable metal (*e.g.* copper or zinc), the former is the case; instead of an oxidisable metal, we find that an incorrodible plate (*e.g.* platinum) immersed in an oxidisable fluid (*e.g.* an acid solution of ferrous sulphate, or an alkaline one of pyrogallol) may often be employed. Gas-films of hydrogen coal-gas and similar oxidisable gases opposed to incorrodible plates immersed in oxidising fluids (*e.g.* platinum in nitric acid or alkaline permanganate solution) furnish cells of the second class. In all cases the E.M.F of the combination falls rapidly with increasing current density, owing to the using up of the gas-film more rapidly than the physical attracting power of the supporting plate can renew it, even under the most favourable conditions, *i.e.* when supported horizontally on the surface of the electrolytic fluid employed so as to be simultaneously in contact therewith and with an atmosphere of the gas experimented with.

In most cases it is desirable that the gas-film plate should not be in direct contact with the alterable fluid surrounding the plate opposed thereto; the cell then takes the form of a two-fluid arrangement, the two liquids being on opposite sides of a porous partition, or contained in separate vessels united by an inverted siphon or asbestos wick, &c. For example, a plate or tray of spongy platinum opposed to a piece of platinum foil, the former being arranged on the surface of a solution of caustic soda in contact with the air, and the latter immersed in a solution of pyrogallol in caustic soda conveniently protected from direct contact with air by being enclosed in an inverted test-tube dipping into a somewhat more dense soda solution connected by a siphon, &c., with the other solution.

We find that with cells of the first class, especially those where air is the gas employed, much more concordant valuations of the E.M.F set up when generating only minute currents may be obtained, than might *à priori* be expected, provided certain precautions are taken; and that fairly accurate valuations are possible of the effect produced by varying the nature of the 'aeration plate' (plate supporting the air-film), the strength and nature of the fluid surrounding it, and so on. Thus the simplest cells of this kind (such as a plate of amalgamated zinc immersed in caustic soda solution, on the surface of which the aeration plate is arranged) appear in general to produce a higher E.M.F the stronger the solution. The effect of varying the aeration plate, all else remaining the same, is independent of the nature of the oxidisable metal, but is influenced to some extent by the strength of the electrolytic fluid, and varies with its nature. For instance, the effect of substituting a tray of spongy platinum for an aeration plate of smooth platinum foil is to cause an increment in the E.M.F of the cell, the numerical value of which is sensibly the same whether zinc or lead be the oxidisable metal opposed, provided the soda solution be the same; but is not the same whether the soda solution be strong or weak; and is widely different, if, instead of caustic soda, dilute sulphuric acid be used as the electrolytic fluid; and similarly in other cases.

Somewhat unexpected results were obtained when certain of the more difficultly oxidisable metals (mercury, silver, and gold) were opposed to aeration plates in contact with appropriate electrolytic fluids: oxidation and solution took place with celerity. Thus mercury and silver readily form mercurous and argentic sulphates if immersed in dilute sulphuric acid on which a platinum sponge aeration plate is arranged, on completing the circuit through a moderately large external resistance: the current produced is readily measurable by inclosing in the circuit a small silver voltameter. Silver similarly dissolves in ammonia solution (preferably containing some ammonium chloride or sulphate) when opposed to an aeration plate, as also does gold in potassium cyanide solution. Hitherto we have not succeeded in dissolving platinum in any combination of the kind.

II. Voltaic Circles producible by the Mutual Neutralisation of Acid and Alkaline Fluids, supplemented by other Agencies.

It has long been known that if an acid and an alkaline solution be united (by means of a wick or siphon, &c.) a considerable current is producible for a short time in the external circuit connecting two plates of platinum, &c., immersed in

the two fluids respectively; but this current very rapidly diminishes to infinitesimal proportions. The usual explanation of this given in the textbooks is that during the passage of the current electrolysis takes place, causing the development of free hydrogen on the surface of the plate in the acid fluid, and of oxygen on that of the other plate, so that an inverse E.M.F. is set up by the incipient gas battery thus produced, which by-and-by becomes practically equal to the E.M.F. due to the chemical action of neutralisation. No direct quantitative proof of this electrolysis, however, appears ever to have been given as regards the hydrogen; whilst as regards the oxygen the main evidence is the observation of Becquerel, that if nitric acid be the acid and caustic potash the alkali, a tolerably constant current is developed, the flow of which is accompanied by continuous evolution of oxygen from the alkali plate, whence the term 'pile à oxygène' applied by him to the combination, the nitric acid being simultaneously reduced to lower oxides of nitrogen.

Whilst studying the action of various gas-film cells, we had occasion to make some experiments with 'neutralisation cells,' *i.e.*, cells in which one essential feature is that an acid and an alkaline fluid are used, which neutralise one another during the action; thus in the case of Becquerel's 'pile à oxygène,' the scheme

$$\begin{array}{l} 2HNO_3 \mid 2KNO_3 \mid 2KOH \\ H_2 \mid 2NO_3\,K \mid 2NO_3\,K \mid OH_2 \mid O \end{array}$$

represents the primary action, the hydrogen, of course, not appearing as such, but reducing the nitric acid. We found it difficult to obtain by titration very sharp figures proving that one equivalent of acid disappears on one side and one of alkali on the other for every equivalent of silver thrown down by the current in a silver voltameter; but our results always at least approximated to this. On the other hand, we found no difficulty at all in proving that in Becquerel's 'pile à oxygène,' 8 milligrams of oxygen (5·6 c.c.s. at 0° and 760 m.m.) are evolved for every 108 milligrams of silver deposited. Moreover, we found that various oxidising fluids can be substituted for nitric acid without affecting this result; thus solution of potassium permanganate or ferricyanide acidulated with sulphuric acid; chromic acid dissolved in sulphuric acid; hydrochloric acid saturated with chlorine; or dilute sulphuric acid saturated with bromine, all cause oxygen evolution (though not all as rapidly as nitric acid) in precisely the quantity equivalent to the silver deposited.

It occurred to us that by suitably modifying the liquids used we might obtain similar quantitative evidence as regards the hydrogen. If nitric acid or other oxidising agent can be reduced by the nascent hydrogen whilst the oxygen escapes, it might be expected that if some highly oxidisable substance is dissolved in the caustic alkali used, the oxygen might be arrested whilst still nascent, whilst conversely the hydrogen escaped free at the other side; and this, in fact, we ultimately succeeded in doing. Several oxidisable substances, however, proved too weak; thus sulphites and ferrocyanides caused no distinct hydrogen evolution; but caustic soda containing hyposulphite (Schützenberger's 'hydrosulphite') or pyrogallol caused continuous evolution of hydrogen in quantity strictly proportionate to the current passing, *i.e.*, 11·2 c.c. normal for every 108 milligrammes of silver deposited.

Precisely the same result was obtained when certain metals not ordinarily soluble in cold acid or alkaline fluids, and simple caustic soda solution were used instead of these alkaline oxidisable fluids with platinum plates. Thus tin or lead immersed in caustic soda and opposed to platinum in dilute sulphuric acid dissolved freely, producing copious evolution of hydrogen from the platinum plate surface. The same result was obtained on substituting copper and ammonia solution for tin and caustic soda; whilst by employing strongly alkaline potassium cyanide solution, mercury, silver, gold, and palladium were readily dissolved with hydrogen evolution from the opposed platinum plate immersed in dilute sulphuric acid. In all these different cases the amount of hydrogen obtained was exactly proportionate to the current flowing, 11·2 cc. being collected for every milligram equivalent of silver deposited in the voltameter.

8. *On the present Aspect of the Question of the Sources of the Nitrogen of Vegetation.* *By* Sir J. B. LAWES, *F.R.S.*, *and* Professor J. H. GILBERT, *F.R.S.*

9. *Dispersion Equivalents and Constitutional Formulæ.* *By* Dr. J. H. GLADSTONE, *F.R.S.*

10. *On a new and rapid Method of Testing Beer and other Alcoholic Liquors.* *By* Dr. WILLIAM BOTT.

At a meeting of brewers recently held at Graz, in Austria, Professor H. Schwarz gave a popular lecture on a new process of estimating the strength and value of alcoholic liquids. The method more particularly applies to beer, but can also be used with other alcoholic fluids; and as it claims the advantage of being equally simple and rapid, and moreover does not require any special chemical knowledge on the part of the operator, it would prove very valuable in the hands of Custom-house officers, publicans, or other people who are frequently called upon to test alcoholic liquors. The whole analysis can be done in three minutes, and consists in

(1) A determination of the specific gravity by means of an accurate hydrometer;

(2) A determination of the index of refraction (this can be very readily done by anybody with one of the so-called Abbé Zeiss refractometers, manufactured by Carl Zeiss at Jena, Germany).

From these two determinations we can easily obtain the difference between the specific gravity of the liquor and that of pure water, also the difference between the respective indices of refraction of the liquor and pure water. Let A denote the difference between the specific gravities, and B that between the indices of refraction of the liquor and pure water respectively; then the general formula is

$$ax - by = A$$
$$cx + dy = B$$

where $x = \%$ of extract
and $y = \%$ of alcohol.

a, b, c, and d are constants, viz.:

$a =$ effect of 1% of extract upon specific gravity.
$b =$ „ alcohol „
$c =$ „ extract upon refraction
$d =$ „ alcohol „

These constants have been determined by a series of very careful experiments and found to be

$$a = 0{\cdot}00393;\ b = 0{\cdot}00163;\ c = 0{\cdot}00150;\ d = 0{\cdot}00062.$$

The only objection to the above method is the expense of an instrument for the determination of the index of refraction; still in cases where a great number of analyses have to be made, the saving of time and trouble would amply repay the first cost.

11. *On some Organic Vanadates.*[1] *By* JOHN A. HALL.

I have obtained a series of organic ortho-vanadates by the action of an alkyl bromide on silver ortho-vanadate. These bodies are yellow liquids, which decompose on distillation under the ordinary pressure, but the lower members can be distilled under reduced pressure.

Methyl vanadate could not be obtained.

Ethyl vanadate boils at 150° C. under a pressure of 120 mm. The vapour density is normal. The specific gravity is 1·167 at 17·5° C.

Printed *in extenso* in the *Journ. of the Chem. Soc.* Oct. 1887.

The refractive indices are—

For Lithium	1·473
„ Sodium	1·481
„ Thallium	1·483

Amyl pyro-vanadate is the only pyro-vanadate which I have been able to obtain in sufficient quantity for analysis.

No meta-vanadates could be obtained, an ether and vanadium pentoxide always being formed.

All these organic vanadates are immediately decomposed by water, with the formation of vanadic acid, thus resembling the organic arsenates more closely than the phosphates.

As I was unable to prepare methyl vanadate, I tried the action of methyl iodide on silver phosphate, and obtained methyl phosphate, a colourless liquid, boiling at 190° C. (uncorrected).

12. *On some Organo-silicon Compounds.* *By* W. B. Hart, *A.I.C.*

Prior to the year 1885, the general method of preparation of organo-silicon compounds consisted in the use of an organo-metallic body, such as the zinc,[1] or the mercuric [2] compound, with silicon chloride. In that year Polis [3] prepared aromatic silicon compounds by the use of Michaelis's general method, which consists in the removal of halogen atoms in a mixture of the halogen-organic compound and silicon chloride by means of sodium, and a consequent linking of the residues.

In every instance mono-halogen derivatives of hydro-carbons have been used, and compounds containing monad radicals have been obtained. It was thought interesting to attempt the preparation of substances containing dyad radicals by the use of di-halogen derivatives.

The method that Polis used was adopted, as being most suitable, and simplest to carry out. It consists in bringing together the required amounts of silicon tetrachloride and di-halogen derivative of the hydrocarbon, diluting with dry ether and adding the calculated quantity of metallic sodium.

Dichlorsilicodiethylenedibromide.

$$\begin{array}{l} CH_2.Br \\ \quad | \\ \left.\begin{array}{l} CH_2 \\ CH_2 \end{array}\right> SiCl_2 \qquad \text{or } (C_2H_4Br)_2SiCl_2 \\ \quad | \\ CH_2.Br \end{array}$$

A mixture of 10 grs. $C_2H_4Br_2$ (2 mols.) and 4·5 grs. $SiCl_4$ (1 mol.) was diluted with thrice its volume of dry ether, the whole being placed in a flask connected with a reversed condenser; and now 5 grs. of metallic sodium (4 mols.), in thin slices, were added, together with a few drops of acetic ether. An action began, and continued, but slowly, for some time. After standing four days in the cold the liquid portion was filtered off, the ether removed by heating up to 100° on the water-bath, and the remaining liquid now distilled. The chief part came over between 130° to 134° as a colourless fuming liquid, which on examination was found to contain silicon, together with chlorine and bromine. It burnt with a luminous flame.

Analysis of halogens gave

7·76 % Cl. 31·48 % Br.

The silicon was too small in quantity to be determined.

The halogen determination was carried out as follows:—

The liquid, weighed out in a bulb, was placed in a closely stoppered bottle, with excess of dilute NH_4HO; the bulb was now broken by shaking. The contents

[1] Friedel & Crafts, *Bull. Soc. Chim.* [2] iii. 356.

[2] Ladenburg, *Ann. Chem. Pharm.* clxxiii. 151.

[3] *Ber. Deutsch. Chem. Ges.* xviii. 1540.

of the bottle were evaporated to dryness on the water-bath in a platinum dish, the residue treated with hot water, filtered, and washed. The filtrate was now precipitated with argentic nitrate in the usual manner, and the precipitate, after filtering, washing, and drying, was weighed. It was now reduced by heating in a current of hydrogen. From these weights the quantities of chlorine and bromine were calculated.

During the distillation, decomposition occurred, and a large quantity of a substance containing silicon remained behind.

The experiment was repeated, the mixture being warmed to about 45° for three or four days and treated as in the previous experiment. On distillation, during which decomposition again took place, it yielded the principal fraction between 120° to 125°, which gave the following analysis:—

Si	5·89 %
Cl	15·05 %
Br	7·07 %

From these numbers we get

$$Si : Cl_2 \text{ or } 1 : 2{\cdot}02.$$

The presence of Br here must be due to decomposition of the substance during distillation, and must exist in the fraction as HBr, since bromine joined to C_2H_4 would not be so split off by NH_4HO.

The halogens were determined as described above. The silicon was estimated by Polis's method,[1] which consists in heating the substance with strong H_2SO_4, and oxidation with a solution of $KMnO_4$.

The method was modified by the use of sodium in a finely divided state. This was prepared by melting the sodium under boiling toluene in a flask, and whilst molten, corking the flask with a good cork and shaking violently for a few seconds. On allowing to cool, the toluene was poured off and the sodium washed with dry ether.

As the chief fraction of the liquid obtained in the last experiment indicated that only half the chlorine was removed from the silicon tetrachloride, and, moreover, a large quantity of sodium was left intact, which probably resulted from incompleteness of the reaction, only half the former quantity of sodium was therefore added.

10 grs. $SiCl_4$ (1 mol.) were mixed with 22 grs. $C_2H_4Br_2$ (2 mols.), and this now diluted with thrice its volume of dry ether; to this 5·7 grs. (2 mols.) of finely divided sodium were added, and a few drops of acetic ether. The reaction proceeded rapidly, and was completed on the water-bath. On allowing to cool, the liquid, which was of a light brown colour, was poured off, and the greater part of the ether distilled. As in the former experiments, decomposition took place on distillation; it was therefore determined to examine the liquid without fractionation at all. The remaining fluid was placed in vacuo over sulphuric acid and allowed to remain there four days. The resulting liquid was now dark brown in colour, thick, and fumed in the air. On exposure to air it became coated with a solid substance, and for this reason was removed to small bulbs for analysis, as quickly as possible.

Si determination. By Polis's method.

0·59 gr. gave 0·11375 SiO_2 = 8·997 % Si

Found.	Calc. for $(C_2H_4Br)_2SiCl_2$
8·997 % Si.	8·88 % Si.

The following equation shows the reaction that occurs:—

$$2C_2H_4Br_2 + SiCl_4 + 2Na_2 = \begin{array}{l} CH_2Br \\ \;| \\ CH_2 \\ CH_2 \\ \;| \\ CH_2Br \end{array}\!\!>SiCl_2 + 2NaCl + 2NaBr$$

[1] *Ber. Deutsch. Chem. Ges.* xix. 1024.

The compound is miscible with ether and benzene. Both sodium chloride and bromide were found in the residue in the flask.

It is a curious fact that these substances cannot be completely burnt. If any one of them is heated on platinum foil in the Bunsen lamp, it does not melt, but carbonises, and leaves a black siliceous residue which cannot be burnt white over the blowpipe flame or even in a current of oxygen. But if the substance is treated with a drop of pure strong sulphuric acid and now heated as before in the Bunsen lamp, a pure white residue is obtained, which, by washing with hot water, leaves a residue of pure silica. Nitric acid also acts in a similar manner.

On account of this, the determination of carbon and hydrogen, in most cases, could not be made, even with the help of lead chromate in oxygen. For the composition of these compounds we are therefore bound, unfortunately, to rely on the indications given by the silicon determinations, aided sometimes by the reactions which these substances undergo on exposure to air.

By exposing the previous compound to air it became solid, and was then insoluble in ether or benzene. It was washed with benzene and dried in vacuo over sulphuric acid. It was of a dark grey colour, and as it was insoluble in the usual solvents, an analysis of it was made, without further purification.

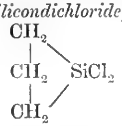
The silicon determination had to suffice, and was carried out by heating the substance on the water-bath with strong nitric acid, when a perfectly white residue of silica was obtained.

0·263 gr. subst. gave 0·150 gr. SiO_2 = 26·6 % Si

Found.	Calc. for. $(C_2H_4)_2$ OSiO
26·6 % Si	24·1 % Si.

But as it is scarcely conceivable that the bromine atoms can be so split off, there is great doubt as to the existence of the above compound.

Trimethylenesilicondichloride, $C_3H_6.SiCl_2$.



This was prepared by mixing 10 grs. $SiCl_4$ (1 mol.) with 11·88 grs. $CH_2.Br.CH_2.CH_2Br$ (1 mol.) and diluting with dry ether. To this 5·4 grs. (2 mols.) of sodium in fine condition and a few drops of acetic ether were added. The number of molecules of either substance taking part in the reaction not being known, excess of $SiCl_4$ was at first used. The reaction began at once and became so violent as to require cooling of the flask. Finally it was warmed on the water-bath. The flask was now cooled and the liquid portion filtered off, and the greater part of the ether removed by evaporation. As a preliminary experiment showed that the liquid decomposed by distillation, it was evaporated in vacuo over sulphuric acid, as in the case of the ethylene compound. The liquid, which was of a dark brown colour and became thick and fumed in the air, was immediately placed in bulbs.

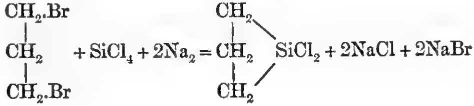
0·23575 gr. subst. gave 0·217 CO_2 = 25·1 % C
0·103 H_2O = 4·8 % H
0·271 gr. subst. gave 0·109 SiO_2 = 18·77 % Si

Found.	Calc. for. $C_3H_6.SiCl_2$
Si 18·77 %	19·85 %
C 25·10 %	25·55 %
H 4·80 %	4·25 %

In the combustion a small residue of carbon was left.

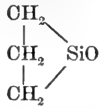
The liquid is miscible with ether and benzene.

The reaction may be expressed as follows:—



Both sodium chloride and bromide were found in the residue in the flask.

Trimethylenesiliconoxide, $C_3H_6.SiO$.



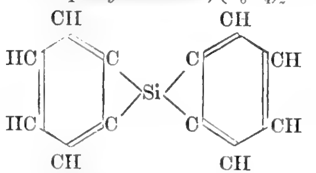
This was obtained by exposing a portion of the previous compound to the air, upon which it became solid and now insoluble in benzene, ether, &c. It was washed with benzene and dried in vacuo over sulphuric acid. The substance had now a dark appearance, and being insoluble in the usual solvents, was analysed without further purification.

0·2025 gr. subst. gave 0·1415 gr. SiO_2 = 32·61 % Si

Found.	Calc. for. $C_3H_6.SiO$
32·61 % Si	32·67 % Si

The action of silicon tetrachloride on aromatic di-halogen derivatives was now tried, and for this purpose the ortho compounds seemed theoretically to offer the most satisfactory results.

Di-o-Diphenylensilicium, $(C_6H_4)_2Si$.



For the preparation of this, 10 grs. $SiCl_4$ (1 mol.) were mixed with 17·2 grs. $C_6H_4{<}^{Cl_1}_{Cl_2}$ (2 mols.) and the mixture diluted with ether. 10·8 grs. of sodium (4 mols.) in fine condition were now added, and the reaction started with a few drops of acetic ether. A violent reaction at once began so as to require cooling of the flask. At the conclusion, the flask was warmed on the water-bath. After cooling the liquid portion was filtered off, the residue on filter being washed with ether. This ether was now removed by distillation and the residual liquid treated with excess of water. A greyish-black substance separated out which was extracted with ether. This ethereal solution was now evaporated on the water-bath, whereby a thick brown oil was obtained, which solidified on cooling. The solid substance was now digested with hot benzene, in order to free it from a dark coloured body. The residue, dried in vacuo over sulphuric acid, was a dark brown solid.

A silicon determination was made by heating the powdered substance with fuming nitric acid to 130° in a sealed tube.

0·142 gr. subst. gave 0·0475 SiO_2 = 15·61 % Si

Found.	Calc. for. $(C_6H_4)_2$ Si
15·61% Si	15·55 % Si.

The reaction may be represented :—

$$2C_6H_4Cl_2 + SiCl_4 + 4Na_2 = (C_6H_4)_2Si + 8NaCl.$$

Action of Sodium Amalgam on $(C_6H_4)_2$ *Si.*

On heating this substance with sodium amalgam in dilute alcoholic solution a curious result was observed. After about an hour, a semi-solid substance separated out, which dissolved on further heating. The liquid was now poured off, and a

sticky substance was found in the flask, and on examination was found to be sodium silicate. The liquid portion, on evaporation, left a semi-solid substance of dark colour, containing carbon and hydrogen but no silicon; it was therefore not examined further.

It would follow, from this easy decomposibility of the compound, that the silicon is combined in a very unstable manner with the two molecules of the dyad radicle phenylene, C_6H_4.

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13. *A new Process for the Preparation of Aconitine.* *By* John Williams, *F.C.S., F.I.C.*

During the past year I have made many experiments upon the best mode of preparing crystallised aconitine, and have succeeded in preparing the alkaloid by a process which yields it better than the one previously employed, and which, as far as I can discover, has not hitherto been described.

The new process for the preparation of aconitine is very simple in outline, but some practical details must be attended to if a successful result is to be obtained. The process is as follows:—

Aconite root (the root of the *Aconitum Napellus*) dried at a very moderate temperature and coarsely ground is thoroughly exhausted with amyl alcohol (fusel oil); the amylic solution so obtained is shaken with dilute acid and water, this acid liquid precipitated with carbonate of soda, and the rough alkaloid produced, dissolved either in ether or alcohol and allowed to crystallise, when the pure alkaloid is obtained.

To carry out this process, however, so as to obtain a satisfactory result several precautions must be taken. First, the aconite root must be carefully chosen, and if possible verified botanically as that of the *A. Napellus.* We have reason to believe that other species of aconite, although yielding alkaloids of great medicinal importance, do not yield an alkaloid identical with that obtained from the *A. Napellus,* and as the British Pharmacopœia gives that plant as the officinal one, great care should be taken to avoid the admixture of other varieties.

The fusel oil used should be of good quality, and free from ordinary spirit; which should be carefully got rid of by washing the oil with water several times, and, if necessary, distilling in a current of steam.

For extracting the root maceration for a few days with frequent stirring, and then percolation, is the most effective. This should be done in the cold. In fact, heat should be avoided as far as possible throughout the whole process.

The percolate is of a pale straw colour, and is not contaminated with the dark oleoresin, which is extracted from the root by ordinary alcohol: this, I need hardly remark, is a very great advantage.

The extraction of the alkaloid from the fusel oil should be effected by weak sulphuric acid and water (about 1 fluid drachm to, say, 4 pints of water). The oil should be shaken with small but successive portions of the dilute acid, and the aqueous liquid tested from time to time with such reagents as double iodide of mercury and potassium, &c.

The weak acid liquid separated from the fusel oil smells strongly of that body, which is to a slight extent soluble in water. To get rid of this the liquid must be shaken with ether (common methylated ether, from which the spirit has been washed out, answers the purpose perfectly). Generally the treatment with the ether should be repeated, as I do not find it easy to separate the whole of the fusel oil at the first operation unless a very large excess of ether is employed.

The aqueous liquid so obtained smelling very strongly of ether should be placed in a water-bath, very gently heated, for a few hours. When cold it will be found to be free from both odour and colour, and in a fit state for precipitation.

The precipitation of the crude alkaloid is best effected by a solution of ordinary carbonate of soda, which I prefer to ammonia.

The precipitate of crude alkaloid, which is nearly white, should be slightly washed and dried, and transferred to a flask or other vessel with great caution, as the alkaloid in this state is very irritating.

The aconitine has now to be dissolved out from this mass by either ether or alcohol, and this must, I think, be done at a boiling temperature, this being the only part of the process in which heat is employed.

The ether should be pure, washed from alcohol, and rendered anhydrous by dried carbonate of potash.

The alkaloid is not very soluble in pure dry ether, and the boiling has to be kept up for some time before the ether is really saturated; it is then filtered into a basin, yielding a perfectly colourless solution, and allowed to evaporate spontaneously, when nearly the whole of the alkaloid is deposited in the crystallised state. The ether may be allowed to evaporate to dryness, and, although the crystals deposited are very small, they give when examined by the microscope uniformly shaped crystals to the end. It frequently happens, however, that a ring of gummy extractive matter (almost colourless) forms around the upper rim of the crystals, due, I suppose, to oxidation, which, even under the most favourable conditions, cannot be entirely prevented. I have found it necessary to add to the dry crystals in the basin a few drachms of pure cold ether. The gummy matter I have alluded to is very soluble in ether, but the crystallised aconitine is not, or rather requires a long time before it dissolves. In this way the crystals can be washed from the gummy matter, which would otherwise contaminate them, and while still damp can be easily transferred to blotting paper, on which they can be allowed to dry spontaneously. Before I adopted this plan I found considerable difficulty in transferring the crystallised alkaloid from the basin to a bottle, and when we consider that the $\frac{1}{3000}$ grain has been found sufficient to kill a mouse, and that probably $\frac{1}{1000}$ grain is sufficient to produce very unpleasant symptoms on man, it can easily be seen that the plan of damping the crystals before removing them is a very necessary precaution.

Crystallising the aconitine from alcohol has some great advantages, but counterbalanced by some disadvantages.

The alkaloid is far more soluble in alcohol than in ether, and on cooling a hot saturated solution crystals are deposited very readily. I have obtained some of quite a quarter of an inch in length, and all the crystals produced are much better defined than those deposited from ether; but unfortunately they are not white, colour begins to show itself very soon after solution, and during the after-evaporation of the alcohol the colour becomes deeper and deeper, thus proving that the alkaloid is much more easily altered when in an alcoholic solution than when it is held in solution in ether, amyl, alcohol, &c. This fact is also of importance as helping to explain how it is that discrepant results were frequently obtained by the old process of working, in which alcohol was used. My effort has been to obtain the alkaloid in its unaltered condition, that is, in the state in which it exists in the plant; and this I think, by the process I have now described, and especially when ether is used as the solvent, is very nearly if not quite accomplished.

I regret to say I am without direct physiological evidence as to the medicinal activity of aconitine made by the process I have described, but still hope that this subject will form a matter of research by one of our most eminent experimentalists, who has promised to take this matter up when he can spare the necessary time.

I have commenced an investigation respecting some of the salts of this alkaloid, but have not been able to continue my experiments, but I hope to be able to do so shortly. The careful analysis of the different products I have obtained has not yet been undertaken, but I hope this may be undertaken shortly.

I may mention that I have tried this process upon a sample of what I have every reason to suppose was the root of the *Aconitum ferox*, but of whose identity I cannot be quite certain.

The alkaloid was yielded in good quantity, and very white, and appeared to be very much more soluble both in ether and alcohol than the aconitine yielded by the *A. Napellus*. It proved most difficult to obtain it in a crystallised form, but I have lately seen a slide which under the microscope proved to be studded with crystals, which appeared to be of the right shape of the true alkaloid, so that it is very probable that the alkaloid from the *A. ferox* contains a crystallisable body which may prove to be the true aconitine, but masked by some other alkaloidal

body not capable of crystallisation as readily as the true alkaloid. As, however, some doubt exists as to the true nature of the root employed, it is perhaps hardly necessary to consider this question further at present.

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14. *Some new Cinnamic Acids.*
By Professor PERKIN *and* Dr. J. B. COHEN.

The object of this paper was to indicate in what manner the preparation of certain substituted cinnamic acids from aromatic aldehydes may be performed, where the ordinary direct method known as Perkin's reaction cannot from the nature of the aldehyde be employed. The cinnamic acids prepared are those derived from Tilmann and Reimer's ortho- and para-salicylic acids. A modification in the separation of the two isomers is described.

The aldehydo-salicylic acids are converted into the ethereal salts.

The ethereal salts are treated with sodium alcoholate, and an atom of sodium introduced into the phenol hydrogen. The resulting compounds are finally heated with sodium acetate and acetic anhydride and the cinnamic acids obtained in this way.

The properties and constitution of these compounds were briefly discussed.

WEDNESDAY, SEPTEMBER 7.

The following Papers were read :—

1. *The Antiseptic Properties of Metallic Salts in relation to their Chemical Composition, and the Periodic Law. By* Professor CARNELLEY *and* Miss ETTA JOHNSTON.

A comparison of all the results obtained by previous observers and by the authors themselves shows: (1) That for the salts of elements of a given family and belonging to the same sub-group the *toxic action alters regularly*, cæteris paribus, *with the atomic weight* of either the positive or negative element of the compound. (2) That this alteration *almost always* takes place in such a way *that the toxic action increases with the atomic weight*, and is therefore strictly analogous to the increase in the toxic action of ordinary alcohols, which Baumetz and Miguel have shown to increase with the atomic weight of the alcohol (cf. Blake, 'Comptes Rendus,' t. xcvi. 439).

It must be understood that these conclusions only hold good provided that the organism and the mode of administration, &c., remain precisely the same for the same series of compounds.

Lithium, beryllium, boron, and fluorine appear to be exceptional, and are in this respect, therefore, analogous to methyl alcohol, which is likewise exceptional among the alcohols, both in toxic and in other properties.

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2. *On the Antiseptic Properties of some of the Fluorine Compounds.*
By WILLIAM THOMSON, *F.R.S.E., F.C.S.*

Some time ago I was engaged in trying to find a substance which would act as a powerful antiseptic, which was not volatile, and which was not destroyed by oxidation. I tried the effects on flour paste, and on meat chopped into small pieces and mixed with water, of a very large number of chemical compounds, and found that those which had the most remarkable antiseptic properties were the compounds of fluorine: hydrofluoric acid, the acid and neutral fluorides of sodium, potassium, and ammonium and the fluosilicates of those bases. Of these compounds I found the neutral sodium fluosilicate to be the one which for its powerful antiseptic and unobjectionable properties was the one which for the general purposes of an antiseptic was perhaps the best suited. This body is not poisonous, possesses no smell,

and is sparingly soluble in water. It has only a very slightly saline taste, and may be therefore employed for preserving food without communicating any taste to it.

Many experiments have been made with it for surgical purposes. A saturated solution which contains 0·61 per cent. of the salt is not irritating to wounds, whilst it possesses greater antiseptic power for animal tissues than one part of perchloride of mercury in 500 of water, which is a stronger solution than that which can be generally employed for surgical purposes without producing poisonous effects.

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3. *On the Composition of Water by Volume.*[1] *By* Alexander Scott, *M.A., D.Sc., F.R.S.E.*

Two years ago, at the meeting of the Association in Aberdeen, the author pointed out that, owing to the difference in the behaviour of oxygen and hydrogen, especially with regard to the effects of pressure on them, it was extremely improbable that the relative volumes in which they combine to form water should be exactly 1 : 2. An account of some preliminary experiments was then given, which seemed to indicate that one volume of oxygen required rather less than two volumes of hydrogen. Many subsequent experiments with larger volumes of gas and different apparatus have confirmed the results then obtained. Over thirty experiments have been performed, and in every case with the same result: the most probable ratio seems to be 1·996 to 1·997 volumes of hydrogen to 1 of oxygen. The apparatus used enables the gases to be prepared of such purity that the amount of nitrogen amounts to only ·7 in 10,400, or about one part in 15,000. The volumes of gas used in the latest experiments are about 280 cubic centimètres of oxygen to 560 cubic centimètres of hydrogen. Taking Regnault's density for oxygen as 15·9627 and the above ratio, we get the atomic weight of oxygen = 15·99.

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4. *On some Vapour Densities at High Temperatures.*[2] *By* Alexander Scott, *M.A., D.Sc., F.R.S.E.*

The following vapour densities were determined by Meyer's method in an apparatus of platinum at a temperature above the melting point of cast iron.

	Experimental value	Theoretical value	Molecular formula
Sodium	25·5	23·	Na
Potassium	37·7	39·	K
Mercury	203·	200·	Hg
Sulphur	67·3	64·	S_2
Iodine	179·3	169·	(I_2+2I)
Cæsium iodide	267·	260·	CsI
Cæsium chloride	179·2	168·5	$CsCl$
Rubidium iodide	221·6	212·	RbI
Rubidium chloride	139·4	120·5	$RbCl$
Potassium iodide	184·1	164·	KI
Silver chloride	160·8	143·5	$AgCl$
Lead chloride	262·7	278·	$PbCl_2$
Manganous chloride	132·3	126·	$MnCl_2$
Ferric chloride	136·1	162·5	$FeCl_3$
Chromic chloride	154·9	159·	$CrCl_3$
Cadmium bromide	242·2	272·	$CdBr_2$
Cadmium iodide	251·1	366·	$Cd+I_2+CdI_2$
Mercuric sulphide	161·8	155·	$(2Hg+S_2)$
Mercurous chloride	193·7	—	Mixtures of $HgCl_2+Hg+Cl_2$
Mercuric chloride	155·6		

[1] *Proc. Roy. Soc.* vol. xlii. p. 396. [2] *Proc. Roy. Soc. Edin.* vol. xiv.

The potassium is perhaps over-corrected for errors in weighing, the number actually found being 44·7; but 92 milligrams of potassium were required to give 22·33 cc. of hydrogen when weighed as in the experiments and thrown into water. The sodium was similarly corrected.

5. *On the Estimation of the Halogens and Sulphur in Organic Compounds. By* R. T. Plimpton, *Ph.D.*

The estimation of the halogens and sulphur in organic compounds is often a matter of some difficulty owing to the want of a sure and generally applicable method of effecting the decomposition of the latter. Heating with nitric acid in a sealed tube does not always suffice for this purpose, and the lime or soda-lime method, besides decomposing certain substances only with the greatest difficulty, is in many respects inconvenient.

A very satisfactory method of decomposition is the gradual introduction of the substance into a Bunsen or hydrogen flame. Provided that the substance be introduced slowly enough, there is no difficulty in effecting its complete decomposition. The products of combustion containing the halogen, partly free and partly as the acid, or the sulphur as sulphurous and sulphuric acids, are drawn through a suitable absorber containing pure soda, and the estimation completed in the usual way.

As to the method of bringing the substance to be analysed into the flame:—Volatile bodies are weighed in a small stoppered tube and dropped into a glass Bunsen burner of suitable shape, the substance gradually evaporating in the current of gas and air. The evaporation is aided or retarded at pleasure by heating or cooling the Bunsen tube.

Non-volatile substances are weighed in a hollow platinum gauze wick which can be raised or lowered inside the burner by means of a rack and pinion, so as to gradually bring it within range of the flame.

A variety of compounds have been analysed by this method with satisfactory results.

In the case of sulphur compounds it is preferable to use hydrogen, as the correction for the sulphur present in the coal gas burnt in the experiment is too considerable.

6. *Vacuum Injector Pumps for use in Chemical Laboratories. By* T. Fairley.

7. *Description of a Shortened Self-acting Sprengel Pump. By* Dr. W. W. J. Nicol.

8. *On the Derivatives and the Constitution of the Pyrocresols.*[1] *By* William Bott, *Ph.D., F.C.S., and* Professor H. Schwarz.

It is about five years since H. Schwarz announced the discovery in coal tar of three new isomerides, which he termed α-, β-, and γ-pyrocresol (Ber. XV. 2201). Some months previous to this publication W. Bott had examined a certain bye-product obtained at the chemical works of Messrs. Crace, Calvert & Co. in Bradford in the manufacture of phenol and cresol, and had, independently of Schwarz, succeeded in isolating from it three new substances and prepared several derivatives of them. Schwarz's pyrocresols were soon recognised to be identical with the bodies obtained by W. Bott, and we finally resolved to jointly pursue their further study. Unfortunately we have been unable to take up the work until recently, so that it is far from complete at the present time.

The mode of preparation of the pure pyrocresols and several derivatives has

[1] The complete original paper is published in the *Journal of the Society of Chemical Industry.*

already been described by H. Schwarz (Ber. XV. 2201), but it will be well to preface our account of the more recent results by a summary of the facts already known, along with such additional points and details as have been found out lately during our investigation.

α-pyrocresol, $C_{15}H_{14}O$, resembles pure anthracene in appearance, and can be readily obtained in large, shining plates, having a beautiful blue fluorescence or in smaller needles. It is readily soluble in benzene, chloroform, carbon tetrachloride, carbon disulphide, less so in acetic acid, alcohol, and ether, and quite insoluble in water and alkalis; the latter do not act upon it even under pressure. It is likewise not acted upon by acetyl chloride, phosphorus trichloride, and $COCl_2$ solution in benzene—from all of which it can be crystallised without decomposition. It melts at about 196°, solidifying again within 4–6° below that temperature. When heated more strongly it readily sublimes in beautiful white flakes. It can be volatilised without decomposition, and its vapour density agrees with the formula given above.

γ-pyrocresol differs from the α-product by its much greater solubility in all solvents, the crystals are less well defined and always needle-shaped. It does not sublime, but can be volatilised without undergoing any change; the vapour density has also been obtained. Its properties are altogether less marked than those of the α-compound. Melting point 104 to 105°.

β-pyrocresol, melting at 124°, stands intermediate between the α- and γ- compounds in all its properties.

Oxides of pyrocresol, $C_{15}H_{12}O_2$.

α-pyrocresol oxide melts at 168° and forms long, light, yellow needles turning darker on exposure to the light. It can be distilled, but does not sublime readily. It is much more soluble in acetic acid and alcohol than α-pyrocresol.

γ-pyrocresol oxide melts at 77°, and forms small rhombic plates turning red on exposure to light.

β-pyrocresol oxide is less well defined; its solidifying point lies at 95°.

The above oxides are obtained by oxidation in acetic acid solution by means of chromic acid. They are indifferent bodies, insoluble in water and alkalis. By gentle reduction with zinc dust, or by HI at a moderate heat, they yield the pyrocresols again. When passed over a long layer of red-hot zinc dust, or heated with a large excess of the strongest HI to a high temperature, they are completely decomposed, yielding the same products as the pyrocresols, which will be described below.

Nitro-compounds, $C_{15}H_8(NO_2)_4O_2$.

Nitric acid alone fails to nitrate pyrocresol completely; the product chiefly consists of the oxide. The pure nitro-compounds are therefore obtained by the action of nitrating mixture upon the oxides and recrystallisation from hot acetic acid or nitrobenzene.

α-tetranitro-pyrocresol oxide forms small light yellow plates, which on heating burn with a flash. It is sparingly soluble in alcohol and insoluble in caustic potash.

β-tetranitro-pyrocresol resembles the α-compound, but is more soluble in alcohol.

γ-tetranitro-pyrocresol forms a yellow and granular mass, and is also more soluble in alcohol than the α-derivative.

By reduction with Na-amalgam or zinc dust amido compounds have been obtained, but have not yet been prepared in the pure state.

Halogen-derivatives.

When α-pyrocresol is dissolved in carbon tetrachloride, and a stream of chlorine passed through for a long time, the liquid assumes a very pungent smell, different from that of chlorine and strongly reminding of phosgene gas. On standing, this odour disappears, and white granular crystals are gradually deposited. These were recrystallised from hot benzene and analysed. The numbers obtained showed

them not to be a uniform product, but by repeated recrystallisation from hot benzene a substance was obtained approximately answering to the formula $C_{15}H_{12}Cl_2O$. By protracted crystallisation we shortly expect to obtain a perfectly pure product. The corresponding β- and γ-derivatives have not yet been prepared.

a-dibrom-pyrocresol $C_{15}H_{12}Br_2O$, obtained by adding Br to the acetic acid solution of pyrocresol, forms thick white elongated plates melting at 215°.

γ and β pyrocresol form very similar compounds, and the oxides also combine with *bromine.*

A *chloride of a-pyrocresol*—probably $C_{15}H_{14}Cl_2$—has been obtained by acting upon a solution of pyrocresol in carbon tetrachloride with a solution of PCl_5 in the same solvent; the chloride is gradually precipitated as a yellowish powder, which on standing soon decomposes, forming a resinous, brown mass. The β and γ isomerides have not yet been prepared. When dry α-pyrocresol is mixed with PCl_5 and heated; a green mass is formed soluble in benzene or chloroform with a beautiful green colour. Upon strongly heating in an oil bath the green colour disappears. The final product, after being well washed with hot water to remove phosphorus chlorides, is found to contain chlorine, but cannot be recrystallised, the solutions invariably drying up to a hard, transparent resin.

Sulpho-derivatives.

The pyrocresols can be sulphonated, two of the hydrogen atoms being replaceable by SO_3H. The Ba- and Na-sulphonates have been prepared. After oxidising sulphonation no longer takes place, hence it would seem that the hydrogen atoms replaceable by SO_3H are the same which are exchanged for oxygen upon oxidation.

Reduction of the Pyrocresols.

The first attempts to effect a reduction of the pyrocresols failed on account of the extreme stability of these bodies. Only recently we have succeeded in reducing α-pyrocresol, and by preliminary experiments have found that β-and γ-pyrocresol can also be reduced, but so far we have only studied the α-derivative more closely. On heating a-pyrocresol in sealed tubes with 80 parts of a solution of HI in acetic acid or water and excess of amorphous phosphorus to 300°, a copious separation of iodine took place, and an oily liquid was found floating on top of the mixture. The contents of the tubes were neutralised, distilled with superheated steam, and the oil obtained dried with KHO, and repeatedly distilled over metallic potassium. The pure oil is colourless and non-fluorescent, it has a slight smell reminding of paraffins, and does not solidify even in a freezing mixture, nor do any of the different parts obtained from it by fractionation. Upon fractionating the oil turned out to be a mixture; the portion boiling about 275° was collected and analysed, the analysis corresponding to the formula $C_{15}H_{32}$; but of course the exact amount of hydrogen cannot be ascertained by analysis only. Three vapour density determinations in an atmosphere of hydrogen and diphenylamine bath by V. Meyer's method gave the following data:

	I.	II.	III.
G =	0·1035	0·0820	0·1045
V =	11	8·7	11·8
t =	10·50	6·5	9·8
B =	757	763·2	755
d =	110·96	108·48	104·32 (H = 1)

Mean: 107·92 (calculated for $C_{15}H_{32}$: 106).

The oil cannot be nitrated by HNO_3 or nitrating mixture; upon heating with HNO_3 a kind of resin is formed lighter than water. Bromine and strong H_2SO_4 scarcely act upon it. The quantity of the oil obtained so far was insufficient for further tests, and the lower boiling portion could not be examined more completely for the same reason. Experiments to prepare larger quantities are now being made.

When α-pyrocresol is slowly distilled over a very long layer of hot zinc dust in a current of dry CO or hydrogen, a soft, yellowish mass is formed, strongly smelling of anise-seed oil. By distillation with steam this yields an oil identical with that obtained by reduction in the wet way, and a solid residue consisting of unaltered pyrocresol.

No definite views regarding the constitution of the pyrocresols can be proffered at the present stage of our investigation, but we may safely draw several conclusions from the results so far obtained, more particularly in the case of α-pyrocresol. Taking the empirical formula $C_{15}H_{14}O$ for granted—and it must in the worst case be a very near approach to the truth, as only the hydrogen might be slightly more or less—the chief point to ascertain is the position of the oxygen atom. The absence of a hydroxyl group is shown by the fact that acid chlorides, $COCl_2$ and PCl_3, as well as alkalis have no action upon the body. Hence the oxygen atom must be directly linked to carbon, and this admits of two possibilities, viz., a carbonyl group or no carbonyl group. The presence of the CO group would impart to the substance the general character of a ketone, but, unlike the ketones, it does not under any circumstances and experimental conditions combine with hydroxylamine or Fisher's reagent—and the same applies to γ- and β-pyrocresol. The absence of the carbonyl group is rendered still more probable by the circumstance that no acid oxidation product could be obtained, and that upon reduction no disubstituted methane—viz., an isomeride of ditolyl methane seems to be formed. From all this we are led to believe that α-pyrocresol and its isomers are anhydrides similar to diphenyl ether, and that they consist of two chains held together by an oxygen atom—thus:

$$\begin{matrix} C_x H_x C \\ C_y H_y C \end{matrix} > O$$

As to the exact nature and structure of the two chains, and the relative position of the oxygen atom joining them, we cannot at present offer any opinion, until we shall have more closely studied the reduction products and the dichloride obtained by PCl_5. The investigation of these and other derivatives is being proceeded with, and, we trust, will soon lead to decisive results.

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9. *Apparatus for the Examination of Air.* By Dr. RANSOME.

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10. *Apparatus for demonstrating the Explosion of Nitro-Glycerine.* By P. BRAHAM, *F.C.S.*

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION—HENRY WOODWARD, LL.D., F.R.S., F.G.S.

THURSDAY, SEPTEMBER 1.

The PRESIDENT delivered the following Address:—

SINCE I received the friendly intimation from Professor Bonney, your distinguished and able President of last year, that the Council of this Association had done me the honour to select me to occupy the presidential chair of this Section which he had vacated, I have been greatly exercised as to what subject to choose for the brief address with which it has now become customary to open the Session. Not that there is any lack of materials ready to hand for the purpose—on the contrary, the subjects embraced by geology are now so varied and extensive that the effort to focus them in a single mind is ever becoming a more difficult task to accomplish, and demands the literary skill of a Lyell or a Geikie to marshal and arrange them from year to year in a manner suitable for presentation to you at our annual gathering.

Foremost in interest must necessarily be that which relates to our Home Affairs, and in this I have been most kindly favoured by Dr. A. Geikie, the Director-General of the Geological Survey of Great Britain, who sends me a brief notice of the progress of the Survey for 1886, taken partly from his Annual Report as Director-General and partly from information supplied by the office through the kindness of Mr. William Topley, our Recording Secretary. The following is the statement which I have received:—

The survey of the solid geology of England and Wales was completed at the end of 1883, and the field-staff has since been occupied in surveying the drift-deposits, making at the same time such revisions of the ordinary (solid) geology as may be necessary. In the north and east of England the drift and solid have been surveyed at the same time. The areas examined in the earlier days of the survey, in the south, centre, and west of England, and in Wales, were done for the solid rocks only.

In order to meet the great need for a general map of England and Wales on a moderate scale, one is being engraved by the Survey on the scale of 4 miles to 1 inch (1 : 253440), and will be issued in fifteen sheets.

A few of the survey memoirs relate to large areas, and give complete descriptions of the formations therein exposed, but most of the memoirs are explanations of special sheets of the map. A series of monographs is now in preparation giving full descriptions of special formations. Mr. Whitaker has charge of that on the Lower Tertiaries; Mr. H. B. Woodward and Mr. C. Fox-Strangways are preparing the Jurassic memoir, the former taking the rocks south of the Humber, and the latter those of Yorkshire; Mr. Jukes-Browne is writing the Cretaceous monograph; and Mr. Clement Reid that on the Pliocene Beds.

In Scotland some advance has been made in mapping the important and complicated area of the north-west Highlands. The surveyors there were chiefly engaged between Loch Stack and Ullapool, subsequently completing the area about Durness and Eriboll. The other parts of Scotland now being surveyed are the

north-eastern and the western side of the Grampians, all south of the latter having been already completed.

Ireland is entirely surveyed with the exception of a small area in Donegal, which will probably be completed this year. This district is of interest from its resemblance to the north-west Highlands, and from the problems which it presents as to the origin of the crystalline schists. The recent discovery of organic remains amongst the Donegal schists adds additional interest to this inquiry.

The publications of the Survey during the past year are as follows:—England and Wales, six sheets of the map, two sheets of horizontal sections, three of vertical sections, and six memoirs; Scotland, three maps and one memoir; Ireland, two maps and six memoirs.

The next matter which has arisen since our last meeting relates to our Colonies, and comes to us in the shape of a message from the retiring President of the Association, Sir William Dawson, who has embodied his ideas in a letter to the President of the Royal Society (Professor Stokes), copies of which have been sent also to all the learned Societies. To the former I am indebted for a copy, accompanied by a favourable report thereon from the Royal Society of Canada.

As the object of this communication is one in which I am sure we, as Englishmen, must all feel a hearty sympathy, appealing as it does to our patriotism in its widest sense, as well as to our devotion for and interest in the science of geology, I feel I shall not need to apologise for introducing it to your notice here.

We are invited by it to enrol ourselves, as geologists, in a Federal Union, composed of all our brethren at home, in our Colonies, and in all the dependencies of the British Crown. Nor are we to stop here, for when this has been satisfactorily accomplished it is suggested that we should invite our English-speaking cousins of the great United States, with whom we are already in such close alliance upon so many objects of common scientific interest, to join our Geological Confederation, and, having thus obtained an overwhelming majority, we are to proceed—without armies or vessels of war—to extend our peaceful conquest over every country on the habitable globe, urging and persuading those countries who have not established geological surveys to do so forthwith, and inviting those who have surveys of their own to join our British Association Geological Union. And when all has been accomplished in this direction our exertions as a confederacy may well be extended to secure the mapping of all those outlying regions of the earth's surface at present imperfectly known or still geologically unexplored.

Suggestions such as these could hardly come at a more fitting and appropriate moment, for are we not now on the eve of the completion of the geological surveys of the British Islands? if such a task can ever be said to be completed which has occupied the attentive study of so many able geologists during the last eighty years or more, and from the very nature of the case must always require additional research and revision.

India, Africa, and our Colonies may all hope for future assistance from the many geological students now being trained in our schools and colleges, who may not be required in the near future for home surveys, and must needs go further afield to win their title of admission to the ancient and honourable order of 'Knights of the Hammer.'

This idea of scientific federation was referred to by Professor Huxley in his Presidential Address to the Royal Society in 1885, and subsequently by the present President (Professor G. G. Stokes) in November last.

If we could devise a scheme by which we might, from time to time, recognise in a suitable manner—whether by corresponding membership, or honorary fellowship, or by medals and awards—as Professor Huxley has suggested, the good scientific work being done by members of the many societies in our distant colonies of Canada, South Africa, Australia, New Zealand, and elsewhere, that would indeed be a step in the right direction, and would doubtless prove most helpful and encouraging to all our fellow-geologists abroad.

The Geological Society of London, no doubt, to some extent covers this ground; but it should be noticed that in the view of this Society our Colonies and other

dependencies are not, and I think rightly, recognised as foreigners, that designation being employed for those who are not in any sense subjects of the Queen.

As a consequence, the geologists of our Colonies are not looked upon as eligible for honorary connection with the Geological Society, and though in the distribution of the medals and awards their work is no doubt noticed, yet that is now so important and extensive that it might be desirable to secure for it a more specific and extensive recognition than has hitherto perhaps been possible.

Might we not also through the home influence we could bring to bear by means of this great Section of the British Association succeed in inducing our practical colonial governments to see the enormous commercial as well as scientific gain that must eventually accrue to themselves if they would, with wise liberality, continue to completion their much-needed geological surveys, instead of (as has too often happened) abandoning the work before its end has been attained, or making its maintenance from year to year contingent on the chance discovery of gold, or the successful boring for coal or water—results not always to be attained within twelve months by a geologist in a new country, however good he may be, unless he have a fairy godmother or a divining-rod at his command?

If by means of our confederation such useful and helpful works can be inaugurated, we shall have fulfilled an object well worthy the initiation of Sir William Dawson, and of all those whose names may be connected with so laudable an undertaking.

Nor need such a development of the work of this Section interfere in any way with the labours of the 'International Geological Congress,' which occupies a distinct field of its own; for whatever we might accomplish in carrying out the suggestions put forward by Sir William Dawson would really be in effect to second and support—not to hinder—the work of that most useful body of geologists.

Our next topic relates to Foreign Affairs.

The International Geological Congress, which met in Bologna in 1881, and in Berlin in 1885, will hold its next meeting in London in 1888. This year the Committee of the Congress on Geological Nomenclature will meet during the Association week at Manchester. Professor Capellini, of Bologna, is the President of this Committee, and Professor Dewalque, of Liège, is the Secretary. Its object is to discuss various questions respecting the classification and nomenclature of European rocks, and to report thereon to the Congress in London.

It is quite certain that a large number of Continental and American geologists will be present in London next year, and it rests with English geologists to determine whether the meeting shall be as successful as those which have preceded it. The Berlin Congress left the arrangement in the hands of a small committee of English members (Messrs. Blanford, Geikie, Hughes, and Topley), and advantage will probably be taken of the presence of so many geologists in Manchester to further the organisation of the English meeting.

The occasion of the Congress visiting London next year should also be a sufficient reason to enlist new members here, and it is to be hoped that a very cordial reception will be accorded to all those who come from abroad to attend the meeting. It ought to be a great success, and deserves our warmest sympathies and co-operation.

Geology seems, at present, to be passing through what may not inaptly be termed a transitional or metamorphic period in its history, when old-established ideas are rapidly melting away, and under fresh influences are crystallising out into quite other forms.

'New lights for old' is the popular cry both in science and politics, and, like the Athenians, nothing delights us more than to hear tell of some new thing.

If the proposition lately made by Professor Judd, the President of the Geological Society in London, in his recently delivered Anniversary Address, holds good, that mineralogy is the father of geology, it seems not improbable that, like Saturn's offspring, our science is in danger of being devoured by its reputed parent; for certainly mineralogy, in the form of petrology, has of late years most largely occupied the geological field, whilst palæontology, once the favourite child of geology, is in its turn threatened with imminent extinction, as a separate study, by

biology, which, without any substantial gain, now replaces, *in name only,* the hitherto better known sciences of botany and zoology.

Indeed, could the views so eloquently put forward by Professor Judd be maintained, mineralogy itself would have to be added to the list of sciences included under biology. But notwithstanding the well-known aphorism of Linnæus—

Lapides crescunt, Vegetabilia crescunt et vivunt;
Animalia crescunt, vivunt, et sentiunt—

the growth of the first is of a totally different nature from that which takes place in the last.

Minerals, or more properly crystals, increase or grow in size by additions to their *external surfaces* of molecules of matter identical with themselves. They are therefore as a rule homogeneous throughout, almost rigid, and remain under ordinary circumstances unchanged irrespective of time.

Plants and animals, on the contrary, increase by intussusception, or the taking of matter within their tissues. Their bodies are *not homogeneous,* and they exhibit all the various phenomena of growth and decay.

We stand, then, still like 'watchers on the threshold,' not yet admitted beyond the veil. We are not prepared to include minerals in the study of living beings, nor are we, I submit, any nearer the solution of the problem, What is life? whether we call it '*vitality*' or '*vital force*;' nor can we produce it like 'electricity' or 'electrical force,' by the aid of mechanics. That it has existed ever since our planet became habitable by living organisms is beyond doubt; and since life first dawned it seems equally certain that this 'vital force' was never at any time extinguished, but, like the sacred flame of Iran, its light has always gladdened our earth with its presence.

I have already referred to the vastness and diversity of the domain which geology claims as her own; indeed, we might, if so disposed, pursue our subject in its *cosmical aspect,* and, inviting the astronomer and the physicist to our aid, proceed to consider the evolution of our earth and its subsequent history as a part of the solar system.

Or, taking up *geognosy,* we might inquire into the materials of the earth's substance and the chief rocks and minerals of which its crust is built up.

Should *dynamics* charm us, then we may study the various agencies by which rocks have been formed and altered, and the frequent changes in relation to sea and land which the terrestrial surface has undergone in former times.

Does *rock-architecture* attract us? It is ours to inquire how the various materials of the earth came to be arranged as we find them—whether wrought by living agents, or ejected by volcanic forces, or laid down quietly by water.

Or is *chronology* the object of our study? Then our task will be to investigate the well-marked succession of the stratified rocks and the sequence of events which they record.

Again, we might prefer the *physiographical aspect of geology,* embracing the history of the features of the earth and the causes which have brought about its varied conditions of continent and ocean, of mountain and valley, hill and plain, making up that grand diversity of surface which constitutes its scenery.

Yet more, it is within our domain as geologists to investigate *the past life of the globe* through all its successive changes and to trace it from its earliest dawn in Præ-Cambrian times down to its grand development at the present day.

One result of the very vastness of this kingdom is that there is a tendency amongst its subjects to form into separate constituencies, and these in an incredibly short time evolve languages of their own, so that, unless this fissiparity can be successfully arrested, we shall speedily repeat the story of 'the confusion of tongues,' and our geological tower, which once promised by our combined labours to reach grandly heavenwards, may soon cease from building altogether.

This incoherence in our body politic may, I think, be traced to that great development by the microscope in mineralogical geology and petrology, which has no doubt been necessitated by the investigation of those remote Præ-Cambrian or Archæan rock-masses in the north-west Highlands, Shropshire, the Malverns,

South Wales, Cornwall, and the west of Ireland, whose fossils, if they ever existed, have been entirely obliterated[1] by the changes which their matrix has undergone, and whose very stratification has been lost by metamorphic action. In such investigations some of our ablest geologists have now been for long occupied with the best possible results, and Bonney, Callaway, Cole, Davies, Geikie, Hicks, Hull, Judd, Lapworth, Peach, Sorby, Teall, and many others have been labouring most zealously on these most ancient sediments, barren though they be, of life forms and often destitute of bedding.

It is refreshing, however, to find Professor Judd at times abandoning volcanoes and turning his attention most successfully to lizard-hunting with Professor Huxley in the Elgin sandstones or studying the micro-organisms in the cores from the Richmond boring or the valley of the Nile; to see Dr. Hicks leaving his patron St. David far behind and digging for bones in the præ-Glacial caves at St. Asaph. Professor Lapworth, too, we see avoiding Cape Wrath and discoursing on the beauties of Canadian Graptolites and the Cambrian rocks at Nuneaton.

Thus there is still a bond of union connecting stratigraphical geology and palæontology and a common ground of interest whereon all geologists may meet. It should then be our endeavour not to dissociate ourselves or our interest from any subject of geological inquiry, but to maintain the union between all branches of our science and with all workers in whatever field they may labour, adopting for our motto the ancient maxim, '*Vis unita fortior est.*'

Especially should we adhere to the study of palæontology, seeing that it is indissolubly connected with one of the earliest chapters in the history of our science. Indeed, through the evidence afforded by organic remains, William Smith (better known by the title given to him by Professor Sedgwick, 'the father of English geology') was led to those remarkable generalisations as to the identification of strata by means of their contained fossils, which have exercised so great an influence over our own science during the past ninety years, and are still the guiding principle on which our classification of the sedimentary rocks is based. What Wollaston has done for mineralogy and crystallography, William Smith initiated for stratigraphical geology; and we cannot overlook our obligation to Smith whilst we reverence the work of his distinguished contemporary, Wollaston.

Palæontology, or the study of ancient life forms, stands somewhat in relation to geology as the science of archæology does to history, or as zoology and botany to physical geography. But, whereas the investigator of recent living forms deals with entire organisms and can study both their morphological and their physiological history as well as their geographical range, the palæontologist has too often to deal with imperfect remains, many of which have no exact modern representative, and has, in consequence, to look for and seize upon minute characters for his guidance, which the worker on recent forms would probably neglect as too trivial for even specific diagnosis.

The palæontologist, if he would succeed, must in fact be a trained zoologist or botanist, as the case may be, and an accomplished geologist also; such combination of qualities like those possessed by the earlier race of 'naturalists' are less frequently to be met with at the present day. They represent amongst us the same class of men as the 'general practitioner' does in medicine; they are the all-round good scientific men, but not 'specialists.'

Biology, or the study of living things, has now become so vast a field that everyone is compelled to take up some special subject, and in striving to master it he makes his reputation as an authority on this or that group of organisms.

There is much to be said in favour of such a method of working, but I hold that everyone who so elects to spend his life must first of all pass through a thorough grounding in general biology, and should on no account take up special work until he has mastered thoroughly the general principles of scientific classification and the various types of organised beings, otherwise he will be for ever

[1] Traces of fossils are said to have been met with in Donegal, and I have just received evidence of Trilobites in the Upper Green Llanberis slates at Penrhyn, hitherto considered unfossiliferous!

viewing all nature with distorted vision, seeing in fact 'men as trees walking.' If as a student he shall have been nurtured wholly on the anatomy of the *sole*, all objects will be viewed from the standpoint of that one-sided fish. If the cockroach has engrossed his youthful studies, all nature will swarm with *Periplaneta orientalis.*

We have to guard against the starting of *student-specialists.* They must begin by being 'general practitioners' if they are ever to do any good in the world of science, and after serving their time in a museum or elsewhere then by all means let each follow his own 'bent' and devote himself to some particular group, as did Davidson to the *Brachiopoda*, to the exclusion of all else.

It is the absence of 'all-roundness' which has retarded more than any other thing the constant interchange of ideas between zoologists, botanists, and palæontologists, without which science languishes. Biologists as a body do not care to look at or study fossils; they see neither form nor beauty in the petrified fragments of a plant or animal such as would induce them to study these more closely, and they turn to the exquisitely perfect specimens of recent objects in their cabinets with a sigh of relief. But *Nemesis* is at hand, created by our modern system of extreme biological training. The student of to-day is averse to the systematic work of both zoology and palæontology in our museums, and technically inclined craves for nothing so much as to be allowed to imbed some interesting embryo in paraffin and cut it into 10,000 slices.

As a consequence our museums will suffer unless we can revive amongst our students a taste for and a love of general natural history; such, we mean, as the *taste for nature* which excited the enthusiasm of Charles Kingsley and stimulated the zeal of Charles Darwin. We cannot all sail round the world as did Banks and Solander, Darwin, Huxley, Hooker, Wyville Thomson, Moseley, and so many other naturalists, though the mere act of travelling has now become so ridiculously easy that our own Association awoke one morning in Montreal, and may for aught we know find itself some day in Sydney or Melbourne! But we can fully appreciate Nature in a dredging expedition or feel her influence on a moor or mountain, in a quarry or down a mine.

What we want for our students in these high-pressure days are less frequent attendance in the examination room and a more frequent examination of Nature in the field. Our professors must take their men more often afield, and show them how to collect specimens and familiarise them with the aspects of natural objects as seen *without microscopes*, and they will return to their studies with far better and keener eyesight after their own *macroscopic* vision has been enlarged by contact with Nature.

Whoever then takes up the study of fossils must also be well acquainted with the structure of living animals and plants; he may also be expected to go on adding to his store of biological knowledge—but as some division of labour is absolutely essential, the man who pursues palæontological research must be prepared to concentrate all his energies on the elucidation of these extinct organisms, studying, but not occupying himself in describing, recent forms.

In order, however, to work satisfactorily at any particular group of extinct organisms, his eyes and his understanding must go through a long and careful training before he will be able to interpret correctly the appearances presented by the specimen before him, and to avoid the fallacies by which he is liable to be misled arising out of the necessarily imperfect materials and their different modes of preservation in the matrix.

He must learn to distinguish between a suture and a fracture, and to know when a specimen has been distorted by cleavage or other mechanical cause, or altered by mere difference of mineralisation. Such deceptive appearances have too often led to the multiplication of species, and even the creation of spurious genera.

Thus occupied in the investigation of ancient life forms, he will in truth be only writing the first chapters on the botany or the zoology of the earth, and, whilst his carefully obtained results are of the greatest importance to the speculations and conclusions of the geologist, they are equally essential to and a part of biological science.

My friend Dr. Traquair has recently thus expressed, in relation to his own subject, what I have attempted to make more general:—'The man who satisfactorily investigates the structure or determines the systematic position of a fish or reptile *preserved in stone* is as much a zoologist as he who describes a similar creature *preserved in spirits,* though with this difference, that the former task is in some points rather the more difficult, seeing that we have *only the hard parts* to go upon, and these generally in a crushed, fragmentary, or scattered condition. And,' he adds, 'without a genuine interest in, as well as a thorough knowledge of, recent biology no one can hope to produce work of any value in palæontology.'

Of course the value of all palæontological work, as of all zoological or botanical work, must depend entirely upon the care and exactness with which the work is performed.

Time, the great assessor of all human labours, will sit in judgment upon them and pronounce by their durability or instability the comparative value of each.

It appears to me that to the careful palæontological worker, as to the careful archæologist, the greatest merit is due if he succeed correctly in deciphering the too often fragmentary and blurred remains of a bygone age, and giving us in the present an accurate interpretation of a page from the life-history of the past.

Then, too, there is the geological aspect of palæontology. And here I may state that one of the charges made by a brother zoologist against us is 'that we use fossils *merely* as counters by which to record the progress of geological time.'

As well might exception be taken that the milestones along a turnpike road had been used by a traveller to calculate the length of his journey.

But omitting the word *merely* (for fossils have been made to give up many secrets to the investigator besides their age), I gladly accept the charge as conveying a great and important truth.

Do not the historian and the antiquary use the coins and medals dug from the ruins of the dead and long past dynasties of the world as sure guides in the chronology of the human period?

And may not the geologist also use 'the medals of creation'—as Dr. Mantell aptly called them—coined in no counterfeit mint, as the best and most trustworthy guides to enable him to establish the chronology of the stratified rocks of the earth?

Great, then, as is the benefit which zoology has derived from palæontology in enabling the zoologist to learn the earliest appearance in time of each group of organisms, and the modifications in structure, so far as we are enabled to ascertain them, which each may have undergone from the ancient to the modern period—it may be doubted whether even this valuable aid equals the service performed to stratigraphical geology by the careful study of organic remains—in enabling us to write the chronology of the rocks over so large a portion of the habitable globe.

Without fossils stratigraphical geology would be as unsatisfaotory as it would certainly be uninteresting; with their aid it becomes, both in the field and in the cabinet, one of the most attractive and delightful of studies.

Owing to the very nature of sedimentary deposits, being of necessity either lacustrine, estuarine, or marine in origin, our knowledge of the ancient land surfaces of the globe is necessarily very limited, but we know much concerning its old marine areas. These are the more constant and widespread, and it is mainly upon these deposits, and not so much upon the more limited evidences of ancient land surfaces, that our chronology has been based.

Of the antiquity of cave-folk and their contemporary mammalia we may expect to hear the very latest utterances from Professor Boyd Dawkins and Dr. Hicks. The former is also to be congratulated upon his renewed work on the Mammalia in the Palæontographical Society's volume for 1886 (just issued). Professor O. C. Marsh has added a further contribution to American palæontology in the shape of a memoir describing and figuring sixteen new species of Mesozoic mammals from the Upper Jurassic rocks in Wyoming, on the western slope of the Rocky Mountains. Mr. Lydekker has just completed Part V. of his most useful and much-needed Catalogue of the Fossil Mammalia in the British Museum, containing the Sirenia, Cetacea, Edentata, Marsupialia, and Monotremata.

The fossil birds remain to be catalogued. In the Reptilia it is refreshing to see

Professor Huxley once more taking up the pen and writing upon *Hyperodapedon* and *Rhynchosaurus* in his old vigorous and earnest style. We can only regret that his health precludes him from continuous labour, to the no small loss of science. Professor Marsh shortly promises us his memoir on the Sauropoda, the plates of which are progressing rapidly to completion.

Our late veteran chief, Sir Richard Owen, although retired from active official duties, contributes a paper on *Galesaurus planiceps,* a Triassic saurian from South Africa, and a further memoir on *Meiolania* from Lord Howe Island.

Professor Seeley and M. Louis Dollo are both occupied with Dinosauria, the former from the Cape (whence he has also detected part of a mammalian skeleton in the Triassic rocks), and the latter is adding to our knowledge of Iguanodon and other forms from the Wealden of Bernissart.

In the Amphibia, Professor Dr. Herman Credner has added a most valuable paper on the development of *Branchiosaurus,* a small Labyrinthodont from the Keuper of Saxony, in which he has been able successfully to trace the development through a long series of individuals of a water-breathing naked larva of the Palæozoic epoch into an air-breathing adult form, clad in a strong coat of mail.

In fossil ichthyology, A. Wettstein has been occupied in the study of the Eocene fishes of the Glarus slates, and in his recent memoir he shows that out of one fish (*Anenchelum*), so constantly distorted by slaty cleavage, Agassiz had made no fewer than six species. This fish is now found to be identical with the living 'scabbard-fish,' *Lepidopus*; and the author reduces the forty-four species of Glarus fishes to twenty-three and adds four new ones. Among the latter is the first fossil *Remora* yet met with, named *Echeneis glaronensis.* Its first dorsal is modified as a sucker, exactly as in the living *Remora.*

Baron Zigno, of Padua, has figured and described the first entire *Myliobatis,* hitherto discovered in the Eocene of Monte Bolca.

M. Louis Dollo records the occurrence of two skeletons of *Carcharodon heterodon* in the Eocene of Boom, Antwerp, one measuring 7 mètres, the other nearly 9 mètres in length. They are now mounted and exhibited in the Brussels Museum.

Mr. J. F. Whiteaves is commencing to publish the detailed descriptions of the Devonian fishes from Scaumenac Bay, Quebec.

Mr. James Wm. Davis, of Halifax, has produced a second monograph for the Royal Dublin Society. The first, which appeared in 1883, was devoted to the teeth and spines of Elasmobranch fishes from the Carboniferous limestone of Great Britain; the present monograph, illustrated by twenty-four plates, is devoted to the description of the fishes of the Cretaceous rocks of the Lebanon, and makes us acquainted with a wonderful series of Selachian fishes, representing nine genera and sixteen species, of which two genera and twelve species are new to science. The Ganoids comprise two species of Pycnodonts and two forms related to Amia; there are also a number of Teleostean fishes, amongst which are *Pagellus, Beryx, Homonotus, Platax,* and many other genera. Two species of eel, *Anguilla,* are the first Mesozoic examples recorded. Altogether we have ten genera and sixty-three species of fish recorded as new. The author is to be congratulated upon having contributed to fossil ichthyology one of the most extensive works published in recent years.

Mr. Arthur Smith Woodward (a former student of Owens College, Manchester) has this year also contributed numerous papers on fossil fishes: on *Ptychodus* from the Chalk; *Squaloraja* from the Lias; on the Brazilian genus *Rhacolepis*; on a Maltese *Holocentrum*; 'On some Eocene Siluroid Fishes from Bracklesham'; and 'On the Canal-system in the Shields of Pteraspidean Fishes.'

Mr. E. T. Newton describes a *Semionotus* from the Trias of Warwickshire.

Both Mr. James W. Davis and Dr. R. H. Traquair have given us descriptions of the anatomy of *Chondrosteus acipenseroides* from the Lias of Lyme Regis.

Mr. William Davies describes two species of *Pholidophorus* from the Purbeck beds of Swanage, Dorset.

But the groups which have proved of the greatest service in the chronology of the sedimentary rocks have been the Mollusca, the Brachiopoda, and Crustacea

(especially the Trilobita, Phyllopoda, and Ostracoda), the Echinodermata, Corals, Graptolites, Sponges, and Foraminifera.

It would be an interminable task merely to record the workers in the various sections of palæontology, but in glancing at these one cannot prevent many illustrious names arising in one's mind—many who have finished their work, and are reckoned among the fathers of the science, but many also who are still our companions, and from whom we may expect further important help before they lay down their hammer, their lens, and their pen.

In the Cephalopoda the task so lately left by our countryman Dr. Wright, after a long life devoted to palæontological science, has been taken up by Mr. S. S. Buckman, who has already presented one fasciculus of a monograph on the Ammonitidæ of the Inferior Oolite.

The Gasteropoda of the Oolites have an able historian in Mr. W. H. Hudleston, whose contributions on this subject enrich the pages and plates of the 'Geological Magazine' and the 'Proceedings of the Geologists' Association'; the Palæozoic forms are in the hands of Dr. Lindström.

The Lamellibranchiata cry for help at present in vain, and we regret more than ever the loss of Stoliczska, who promised such good work had his life been spared.

The Brachiopoda, so long and so well cared for by Dr. Davidson, now also demand a successor to that illustrious name.

The Polyzoa, which suffered so severe a loss in the death of Mr. Busk, have since been well cared for by Mr. Arthur W. Waters and Mr. Vine.

Until quite lately, the oldest fossil insects known were the six fragments of wings of Neuroptera, from the Devonian of New Brunswick, obtained by Mr. C. F. Hartt and described by Mr. S. H. Scudder. More lately the wing of a cockroach has been obtained from rocks of Silurian age in Calvados, France; whilst almost simultaneously fossil scorpions have been met with by Dr. Hunter, of Carluke, in the Upper Silurian of Lanark, and determined by Mr. B. N. Peach, and from the Upper Silurian of Gotland, described by Dr. Lindström.

These discoveries carry back our records of old land surfaces to a far more remote period than that of the Coal-measures, vast as its distance is removed from recent times.

Mr. B. N. Peach is the discoverer of several scorpions, and I have also recently figured and described three new forms of cockroach and several spined myriapods from the Coal-measures. Another cockroach, also new, which has been kindly sent me for study by Mr. Peach, brings to our knowledge a larval stage of *Blatta* from the Scottish Carboniferous.

Dr. McCook has just added a genus of spiders, *Atypus,* to our Eocene beds from the Isle of Wight.

The Crustacea have found in Mr. B. N. Peach and in Professor Rupert Jones able and willing historians. Mr. Peach has taken up the Carboniferous Macrouran Decapods, and Professor Rupert Jones the Palæozoic Phyllopoda, aided by myself; Professor Jones is attacking the Tertiary and Cretaceous as well as the Palæozoic Ostracoda, so that his hands will be full for many years to come.

The Echinodermata have lost Dr. T. Wright, who for years acted as their monographer in the Palæontographical Society's volumes, but they have secured the services of other accomplished naturalists. Mr. Robert Etheridge, jun., and Dr. P. Herbert Carpenter have produced a grand monograph on the Blastoidea in the British Museum; and no doubt this is but the beginning of good things to come, for although Mr. Etheridge has entered upon a new sphere of work in the Australian Museum, Sydney, Dr. P. Herbert Carpenter hopes to take up the stalked Crinoids before long, and Mr. Percy Sladen, who, with Professor P. Martin Duncan, has already done so much good work amongst the Indian Echinoderms and elsewhere, promises to take the star-fishes in hand for us later on.

The Corals have many friends, chief amongst whom is Professor P. Martin Duncan, and Professor H. A. Nicholson, and various other excellent workers, but they are even a more difficult and a less attractive group than the Echinodermata, and their determination is not so satisfactory, owing to their irregular and heteromorphic growth.

The Stromatoporoids have lost an investigator in the field in Arthur Champernowne, whose unexpected and early loss we all deplore. But in Professor Nicholson they will find a most careful and painstaking monographer, who has already given us one fine instalment of his work in the Palæontographical volume.

In Professor C. Lapworth we have an exponent of the structures and affinities of the Graptolites as a class and of their stratigraphical position in the rocks unsurpassed by any other worker. With him must be associated the names of Barrande, Carruthers, Hopkinson, Nicholson, and a long list of foreign workers, all of whom, however, look upon Lapworth as the highest authority in this group.

In the Spongida we are especially indebted to Dr. G. J. Hinde, first for an excellent, well-illustrated quarto catalogue of these organisms in the geological collection of the British Museum, and secondly for the Palæozoic part of a fine monograph of these for the Palæontographical volume just issued.

Nor must we omit to recall the names of Professor Zittel, of Dr. Carter, of Professor Sollas, and many other able workers in the fossil sponges.

In the Foraminifera we naturally recall the names of D'Orbigny, D'Archiac, Carpenter, Parker, Brady and Jones, and Sir William Dawson, our illustrious ex-President. Professor Rupert Jones is still at work on this group, and has recently published a paper on *Nummulites elegans* from the Eocene beds of Hampshire and the Isle of Wight.

Of late years fossil Botany, too long neglected, has taken a place of note in all those inquiries concerning the origin of floras, the age of the stratified rocks, the former distribution of land surfaces, and especially in all questions relative to the climate of the globe in past times.

Passing over the earlier period of the present century, when fossil botany was known only by the works of Artis, Witham, Schlotheim, Sternberg, Goeppert, Cotta, Lindley and Hutton, Steinhauer and Adolphe Brongniart, we have to recall the names of other workers who have only passed away in our own time, such as Binney, Bunbury, Corda, Bowerbank, Heer, Unger, Schimper, and Massalongo.

In the period of fifty years, whose completion we have just celebrated, the names of our countrymen Binney, Bowerbank, Williamson, and Hooker stand prominently forward contemporarily with those of Geinitz, Unger, Rossmasler, and Schimper in Germany. In 1845 Dawson and Lesquereux entered the field in America, Hooker in England, and one of the ablest writers on fossil plants, Oswald Heer, entered upon his great work in Switzerland. In 1850 Massalongo in Italy, and von Ettingshausen in Austria, were added to the roll of famous palæobotanists, and in 1853 Newberry joined the American field of research. In 1860 the work so long abandoned by Brongniart, in France, was taken up by de Saporta, and it is no small gratification to have him with us here to-day, and to welcome him amongst our distinguished foreign guests.

About the same time my friend and colleague William Carruthers commenced to write on fossil botany, and brought to bear upon the subject that accurate and careful knowledge of living forms without which such investigations must always prove but futile.

It is extremely difficult to estimate the number of species of fossil plants that had been described up to the year 1837, but it probably fell far short of a thousand. In 1828 less than 500 species were known to Brongniart.

In the first edition of 'Morris' Catalogue,' published in 1843, the number of British fossil plants recorded is 628.

Careful lists were published by Goppert and by Unger in 1844 and 1845, giving a total of known species from 1600 to 1800.

In 1849 the number had increased, according to Bronn's 'Index Palæontologicus' to over 2,000, and the following year Unger enumerated 2,421 in his 'Genera et species Plantarum,' rather more than 500 of which may have been British. In 1852 Morris (2nd edition) gives the number of species as 740. Since then, chiefly through the labours of Heer, Ettingshausen, Lesquereux, Massalongo, Unger, and de Saporta, this number has been more than quadrupled. Mr. Gardner estimates that at least 9,000 species must have been described. This great increase

is chiefly due to the more careful exploration of the Tertiary strata, in which the more highly organised and consequently more differentiated plant-forms occur.

The number of plant-remains described in Great Britain during the whole 50 years has been extremely small, but much has been accomplished in the study of fossil plants generally, and in this task no one has been more earnest than Professor Williamson, of Owens College, Manchester.

His investigations of the plants of the coal period have been of the most exhaustive nature, and from his researches into their microscopic structures we are almost as well acquainted with the minute tissues of these ancient denizens of the forests of the Carboniferous epoch as we are with those in the parks around Manchester to-day.

Mr. Carruthers' 'Memoirs on the Coniferæ and Cycadeæ, and on the Fruiting Organs of the Lycopodiaceæ' have greatly advanced our knowledge of these interesting types, heretofore but imperfectly known from their fossil remains.

Mr. R. Kidston has devoted himself most earnestly to the investigation of the fossil plants of our British coalfields, and he has determined not to rest satisfied merely to work out the plants obtained by others in our museums, but he has visited all our coalfields and searched the shales on the spot for himself. The results of his collectings may now be seen in the valuable additions made to the coal-measure series of plants in the British Museum (Natural History).

But it is more especially in reference to the Tertiary flora of Britain that progress has been made of late years.

Thanks to the labours of Mr. J. Starkie Gardner, who has not only obtained abundant materials for an exhaustive monograph with his own hands from Sheppey, Alum Bay, Bournemouth, Reading, Mull, Antrim, and many other localities, but has already favoured us with several memoirs in the Palæontographical Society's annual volumes and elsewhere on the British Eocene flora, we may hope before long to have a more complete history at this period of our islands than we already possess of the flora of the Carboniferous age.

Nor has any research, favoured by the aid of this Association, brought so large a return in beautiful and instructive specimens to our National Museum of Natural History as have the investigations carried out by Mr. J. S. Gardner.

We must not omit to mention Mr. Clement Reid, who has so diligently traced many of the specimens of our existing flora in the Pleistocene strata of the eastern counties.

'Large numbers of ferns and gymnosperms' (says Mr. Gardner) 'have been discovered in Mesozoic rocks, but remains of the interesting monocotyledons which must have accompanied them are provokingly scarce. We know that palms, grasses, &c., appear at certain definite horizons, but we are ignorant regarding their ancestry. We know that temperate floras, largely composed of dicotyledons, flourished as far north as man has been able to penetrate in the Cretaceous and Tertiary periods, but nothing in the least suggesting a transitional form has been found amongst them. Lastly, we have learnt that floras now indigenous to Japan and the Himalayas, to Australia and South America, once inhabited Europe, groups of wholly different plants succeeding and displacing each other in rapid succession on the same spot so as to suggest that the normal condition of floras is one of slow but perpetual migration, and that the term "indigenous" has no geological significance.'

In reference to the question of geographical distribution of organised beings in geological time, the conclusion is strongly forced upon us, from a study of fossil remains, that the great zoological provinces into which the earth's surface and the seas of the globe are now subdivided have been brought about by the limitation of species at no more distant date than the Secondary period, and probably even later than this.

That in Palæozoic times there must have been a great uniformity of marine conditions, and the fauna of each of the primary formations was consequently not only of vast duration but of world-wide extent.

When, as in Carboniferous times, we are enabled to study the contemporary land conditions of the globe, we find they must also have been very uniform, at

least so far as the explored parts of this hemisphere are known, both the fauna and flora at this epoch being co-extensive with the northern hemisphere, indeed in all probability far wider, seeing that identical species occur in the Carboniferous series of Australia and North America. Even those well-marked lines which at present follow more or less closely the isotherms of our hemisphere seem not to have exercised the same influence on the fauna and flora as they do at present. Thus in high northern latitudes and within the arctic circle we find abundant evidence of life in Palæozoic, Mesozoic, and even down to Tertiary times, unaffected by latitude; so that we are justified in assuming that a far milder temperature extended to much higher northern regions than that which at present exists on the globe, and consequently that a larger portion of the earth's surface (as well as its seas) was then habitable.

How great, then, is the field of research still open to our investigation, and how far distant must that day be ere the last problem shall have been solved, and the last chapter written, in the ancient life-history of our earth!

We write in sand, our labour grows,
And with the tide the work o'erflows.

With unskilled hand I have struck here and there only a few chords on the many-toned harmonicon of geology. I fear they may not all have vibrated quite in unison as a perfect composition would; but, however crude the performance has been, I trust that it will not be provocative of discord. If some few ideas suggest themselves as worthy of your acceptance I shall not have spoken altogether idly, nor you have listened so long and so patiently entirely in vain.

The following Papers were read:—

1. *On the Geography of the British Isles in the Carboniferous Period. By* Professor W. BOYD DAWKINS, *F.R.S.*

In the Devonian age the great north-western continent, to which in 1886 I gave the name of Archaia,[1] and which occupied the area of the North Atlantic in the direction of Iceland, Greenland, and a large portion of North America, extended southwards in Britain over the area of the British Isles as far as the line connecting the Lower Thames with the Lower Severn. It was diversified by chains of mighty lakes, embosomed in luxuriant forests of conifers, and various Lepidondendron and Calamitean trees. These lakes probably discharged their waters into the Devonian Sea then covering the southern waters. At the close of this period the British area sank beneath the waters of the sea until it was reduced to a cluster of islands lying off the coastline of Archaia, and each marked by the shingle-beaches.

In dealing with the geography of the British Isles during the Carboniferous period I propose to take the areas of Lancashire and Yorkshire as a starting-point, and to divide the strata into two groups:—

1. The Lower Carboniferous, consisting of—
   - A. The Lower Carboniferous Shales, Sandstones, and Conglomerates.
   - B. The Carboniferous Limestone.
   - C. The Yoredale Series.
2. The Upper Carboniferous, consisting of—
   - D. The Millstone Grit.
   - E, F, and G. The Coal-measures.

The Lower Carboniferous Shales, Sandstones and Conglomerates, A of the above list, rest for the most part unconformably on the older rocks; conformably, however, on the Old Red Sandstone, and vary considerably in thickness, as might be expected from their accumulation on a shore ranging from 4,000 feet in the basin of the Clyde to about 100 feet in South Wales, and being represented under

[1] Lectures before Royal Institution. So called from the *massif* of the continent being composed of rocks of Archaian age.

Ingleborough by shingle resting on eroded reefs of older rocks a few feet thick. They form a band running from the north-east to the south-west on the northern boundary of the central valley of Scotland, and re-appear in the same line on the flanks of the mountains of Donegal in Ireland. From this point they sweep southwards by the hills of Connaught and Kerry, where they are lost in the Atlantic.

They mark the coastline of Archaia against which the sea beat at the beginning of the Carboniferous period. From this coastline Archaia extended over the waters of the Atlantic indefinitely to the north and to the west.

The sea to the south was studded with islands, each marked by the shingle-beaches, the two South Scotch Islands, the Island of Cumbria and of Man, and in Ireland of Mourne and of Wicklow. In North Wales the Lower Carboniferous shingle beds, sand, and mudbanks sweep from the valley of the Conway eastwards and southwards to Llangollen in the direction of Shrewsbury, and in South Wales from St. David's and Pembroke in the direction of Hereford. From these points the coastline is either obliterated or concealed by newer rocks; the land, however, was certainly continued eastward, so as to include the areas of South Staffordshire, Warwickshire, and Charnwood Forest, in Leicestershire, as Jukes pointed out, and has repeatedly been struck in deep borings for coal, which prove the absence of the Lower Carboniferous rocks. For this tract of land the term 'Middle Island' is proposed. It probably extended westwards so as to include the Wicklow Mountains. Its eastern boundary is concealed. Land also existed at this time in Cornwall, and extended westwards to include the Scilly Islands, and to the south-east across the Channel in the direction of the mouth of the Seine, and southwards over Normandy and Brittany. This land, as Bonney has pointed out, constituted a lofty mountainous tract during the later primary ages, barring the waters of the Atlantic from those of the Lower Carboniferous Sea to the east. It may conveniently be termed the South-British land, because it not only includes Cornwall, but also Normandy and Brittany. Whether it was an island, or whether it was connected with the *massif* of Archaia to the west, is an open question.

While these littoral accumulations were being formed on the margin of the land the British area was gradually but unequally sinking, and the waters in the area of Derbyshire became sufficiently deep and clear to allow of the formation of no less than 5,500 feet of limestone. This 'mountain' or Carboniferous limestone thins off from this point in every direction. To the north in Durham and Northumberland and in the central valley of Scotland it is broken up by sandbanks and mudbanks, and becomes a subordinate division in a coalfield. To the south in like manner it alters its physical characters as it approaches Middle Island, in Flint and Denbigh, and it is abruptly brought up by the land in the areas of South Stafford and Charnwood. On the southern shores of Middle Island it is reduced in Pembrokeshire, according to Ramsay, from a thickness of 2,500 feet to nothing in a distance of 12 miles.

During the accumulation of the Yoredale sandbanks and mudbanks the sea was becoming more and more shallow until in the time of the Millstone Grit it was mainly occupied by littoral deposits. These two divisions in North Lancashire, in Pendle Hill, are no less respectively than 4,675 and 5,500 feet.

We may learn from the study of the isolated coalfields that the great horizontal tract of forest-clad alluvia which constitute the Coal-measures occupied nearly the whole area of the British Isles in the Upper Carboniferous age from the Scotch highlands southward, the dead flat being broken only by the higher lands —the old islands of the Lower Carboniferous Sea—which I have already described. They were formed in, indeed, a delta of a mighty river analogous in every particular to that of the Mississippi—a delta in which, from time to time, the forest growths became depressed beneath the water until the whole thickness (7,200 feet in Lancashire) was accumulated of coal seams and associated sandstones and shales. After each depression the forest spread again over the bare expanse of sand and mud piled up in the submerged area. In this manner we can account for the fact that there is scarcely any, if any, change to be noted in the flora during the great length of time implied by the great thickness of the Carboniferous strata.

The enormous extent of the Upper Carboniferous delta implies a river of great

magnitude, and a continent of corresponding size, to give the necessary drainage area—to wit, the continent of Archaia.

To this northern and western land may be traced the pebbles and groups of pebbles found in the coal seams of Lancashire—such, for example, as the Trencherbone seam, near Kearsley—and which have probably been brought down in flood time from the uplands. They are, with few exceptions—one a granite—quartzites, and have been derived from conglomerates formed by the break-up of the Cambrian and Ordovicean rocks—most probably from the Old Red Sandstone Conglomerates of Scotland, or of a continuation of Scotland in the direction of Norway.

It only remains for me to add that in this paper I have entered upon the labours of Phillips, Godwin-Austen, Jukes, and Hull, and that I have dealt only in outline with a difficult and complicated question.

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2. *On the Structure of the Millstone Grit of the Pennine Chain. By* Professor W. BOYD DAWKINS, *F.R.S.*

In this communication attention was drawn to the normal constitution of the rock and to the granular quartz and the orthoclase sometimes sufficiently fresh to show the cleavage, which have evidently been derived from the destruction of granite rocks, and are not much rolled. The orthoclase has generally been reduced to kaolin by the passage of waters charged with carbonic acid, and sometimes is wholly removed, the cavities being coated with a secondary deposit of quartz crystals derived from the break-up of the orthoclase. The sand-grains also are coated in the same way. It is an ancient sandbank of a sea that beat upon rocks composed of granite and crystalline schists and later rocks, as is proved by the pebbles of vein quartz and the rolled garnets of the rocks which formed at this time the *massif* of Archaia.

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3. *On Foreign Boulders in Coal Seams. By* MARK STIRRUP, *F.G.S.*

Among many interesting problems connected with the Carboniferous rocks still awaiting solution, not the least interesting one is that of the mode of occurrence and the source of the foreign boulders which are occasionally found in our coal seams.

The importance that attaches to these boulders is that, could we read their history aright and ascertain whence they came, it would give us some clue to the physical features of the old land areas in pre-Carboniferous times, and enable the palæophysiographer to construct his charts with a greater probability of correctness than at present. Furthermore, could the means by which these boulders were deposited in the coal be clearly pointed out, they would either confirm or refute the arguments of those physicists who contend that this earth of ours has experienced great periodic alternations of climate, cycles of cold and heat, due to cosmic causes acting through all time.

The presence of these foreign boulders in coal seams has been long known, but they have always been considered rare and phenomenal. The late Mr. E. W. Binney in 1851 read a paper on the subject before the Manchester Literary and Philosophical Society (vol. ix. second series, p. 306), in which he describes and figures some rounded grey quartzose stones from the 4-feet mine at Patricroft and from another seam under the same mine at Pendleton.

Other notices may be found in the 'Transactions of the Manchester Geological Society' by Mr. John Plant, the late Mr. J. Aitken, and others.

These boulders are, as a rule, hard siliceous grits or quartzites, ranging in colour from pale to dark grey, and would betoken by their character and mineralogical composition that they were all derived from one common source.

Though varying often in form and size they have this common characteristic—that they are smoothed, often polished, with corners rounded off by abrasion.

Their forms are various—roughly quadrangular, irregularly ovoid or elliptical, occasionally globular, and all have evidently been water-worn before being deposited in the coal strata. A thin film of coal or shale, according to the matrix, is

often found closely and firmly adherent to the surface, and this coating has not unfrequently the appearance of the polished surface known as 'slickensides,' which has probably been produced by the great pressure to which they have been subjected. The surface, though smooth and often polished as described, does not exhibit lines and scratches, such as those seen on boulders from the glacial drift.

These erratics range in size from small pebbles to large boulders, weighing from 100 lbs. to 200 lbs. and upwards.

The specimens exhibited have been kindly sent by several members of the Manchester Geological Society connected with Lancashire collieries—viz., Mr. George Wild, Mr. James Radcliffe, Mr. H. A. Woodward, Mr. H. H. Bolton, and others.

Mr. George Wild's specimens are mainly from the Arley mine of Burnley, the lowest seam in the Middle Coal-measures. Though small in size they are interesting for the variety they exhibit of white and grey quartzites. Mr. James Radcliffe's specimens are from the Roger seam of the Astley pit, Dukinfield, and have been recently described before the London Geological Society ('Q. J. Geol. Soc.' vol. xliii. p. 599). Two of these, of the usual grey quartzite, weigh respectively 100 lbs. and 156 lbs.

The Roger seam is upwards of 500 yards above the Arley mine, the recognised base of the Middle Coal-measures of Lancashire. Mr. H. A. Woodward, of the Clifton and Kersley collieries, near Manchester, reporting upon some recent boulders found in the pits, says that they are found in clusters as a rule, but in a few cases singly.

They are common to all seams of this district, but are most plentiful in the Trencherbone seam, the 6-feet or 9-feet seam of the Wigan district.

They are found in the coal, in the roof, and sometimes half-embedded in both coal and roof, at depths from surface of 720 and 1,800 feet.

All the boulders mentioned come from the Middle Coal-measures of Lancashire from the Arley mine as the base to the upper part of the Middle series.

Some interesting boulders have been recently found in the Lower Coal-measures at Bacup. They are from the Gannister Coal or Mountain mine, upwards of 1,000 feet below the Arley. One of these is a granite, which will be referred to later on; another small one of quartz felsite, similar to rocks of the Lake district; and another of grit, among the grains of which a considerable amount of iron pyrites is disseminated.

These boulders are by no means confined to the Lancashire coalfield; they have been recorded from the Leicestershire coalfield by Mr. Gresley and by other observers from the North Staffordshire, the Forest of Dean, the South Wales, and other of our English coalfields.

Yet another important fact to bear in mind when considering their distribution is that they are not restricted to England nor to Europe. They are found also in the coal seams of the United States, where the character and the composition of the boulders and their position in the coal seams accord in all respects with those of our own country, and the description given of them by American geologists would very well apply to our own.

Professor Orton, State Geologist of Ohio, says: 'These boulders, though uncommon, are still in the aggregate numerous, and agree in mineralogical characters.'

References will be found to these Ohio boulders in 'Geology of Ohio,' vol. v. and 'Report of Progress Ohio Geological Survey for 1870.'

Fragments of three of these Ohio boulders have been kindly sent to me by Professor Orton, and I have had thin sections prepared of them and of some of the Lancashire boulders. These have been submitted to Professor Bonney, who has most obligingly examined them and remarked upon them.

Of the Ohio grey quartzite boulders he says they have the same general characters as the Dukinfield boulders, but a little more distinctly cemented by secondary quartz. Summing up, Professor Bonney says: 'Of these, most of them tell us nothing beyond the fact that they are, no doubt, Palæozoic rocks, and have probably derived their materials from old granitoid rocks. The "granite" specimen is interesting. It is a rock much more ancient than the Carboniferous, and the rounded inclusions

of quartz in the felspar is a thing which is specially common to the granitoid rocks of the Hebridean series of Britain and the Laurentian of America. But of course I cannot assert it is Hebridean, only it reminds me of Hebridean.'

The presence of these foreign boulders in coal seams opens out several interesting inquiries. The two main questions are—Whence did they come? and by what means were they brought into their present position?

Many suggestions have been hazarded and theories broached to answer these questions, but none as yet fully accounts for all the phenomena connected with these boulders. We have seen that they are not confined to our own little island, but are found under exactly similar conditions in North America; so, whatever the agent of transport was, whether water or ice, it was evidently active over a large part of the northern hemisphere.

The similarity and almost identity of the mineralogical composition of these boulders is very remarkable, coming as they do from areas so widely separated as are our own shores from those of America.

They are evidently older than any rocks of the Carboniferous period, but whether they are fragments of some ancient continent of Cambrian or Archæan age has yet to be decided.

As to the mode of deposition of these boulders in the seams of coal, many objections surround the theory of transport by currents of water, seeing the great size of some of these blocks and the total absence of any associated clays or sands.

Transport by ice, floating icebergs in a summer sea, would, perhaps, explain better than any other theory their position, and often isolation, in strata singularly free from extraneous matter.

Professor Croll, in his 'Climate and Time,' suggests that the Carboniferous flora was the growth of one of those assumed interglacial stages, recurrent during all geological time, and that during the intervening cold periods represented, I presume, by the grits and sandstones, we had the most favourable conditions for entombing and preserving the vegetable life of that epoch.

But an objection to this theory is, there is nothing in the character of the vegetation during the whole of the long period embraced by the Coal-measures to support the argument. The flora is identical and indicates no change of climate during the millenniums of millenniums represented by the thousands of feet of thickness of the Coal-measure rocks.

Such are some of the unsolved problems represented by these boulders, and nothing but a careful accumulation of facts with regard to them will help to unravel their mysterious history.

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4. *On the Organic Origin of the Chert in the Carboniferous Limestone Series of Ireland and its Similarity to that in the Corresponding Strata in North Wales and Yorkshire.*[1] *By* GEORGE JENNINGS HINDE, *Ph.D.*

The origin of the chert in the upper division of the carboniferous limestone in Ireland was the subject of a joint paper by Messrs. Hull and Hardman[2] in 1878, in which they stated that the silica of which it is composed was derived *directly* from the sea-water; that the chert was essentially a pseudomorphic rock consisting of gelatinous silica replacing limestone of organic origin; and that it was *not* due to the action of organisms with siliceous skeletons, such as diatomaceæ, polycystinæ, and the spicules of sponges. In the same year M. A. Renard attributed a similar origin to the phthanites of the Carboniferous series of

[1] The original paper has been published *in extenso* in the *Geol. Mag.* for October 1887, N.S. Dec. 3, vol. iv. pp. 435–446.

[2] On the Nature and Origin of the Beds of Chert in the Upper Carboniferous Limestone of Ireland. By Professor Edward Hull, M.A., F.R.S., Director of the Geological Survey of Ireland.

On the Chemical Composition of Chert and the Chemistry of the Process by which it is formed: By Edward F. Hardman, F.C.S.—*Scientific Transactions Royal Dublin Society*, vol. i. N.S. 1878, pp. 71–94, pl. iii.

Belgium—'Bulletin de l'Acad. Royale de Belgique,' s. 2, t. 46, pp. 471–499. In 1881 Professor Sollas pointed out that in sections of some of the very specimens described and figured by Professor Hull in the paper referred to above 'sponge spicules make up the larger part of the chert'—'Ann. and Mag. Nat. Hist.' s. 5, vol. vii. p. 141. In 1885 I suggested that the Irish chert was probably derived from sponge remains, the same as the Cretaceous chert in the south of England—'Phil. Trans.' Part II. 1885, p. 433. During the present year Messrs. Hull and Hardman brought papers before the Royal Society reiterating their former views as to the inorganic origin of the chert, and stating that there was absolutely no evidence for the suggestion I had made as to the derivation of the silica of the chert from sponge remains, and that I had mistaken fragments of crinoids for sponge spicules—'Proc. Royal Soc.' vol. xlii. pp. 304 *et seq.*

In order if possible to determine this question, I went to Ireland last July and examined the carboniferous chert in the localities whence Professor Hull obtained the specimens on which he founded his conclusions as to its inorganic origin, visiting various places in Queen's County and Kilkenny to the south, and in Fermanagh and Sligo to the north-west of Ireland, and in the vicinity of Dublin. The chert in these different localities is mainly of the same character—a dark, hard, compact, siliceous rock, frequently without being affected by acid, though in the cherty limestones, calcite, in the form of organic structures, is intermingled in various proportions with the silica. The chert occurs either in layers of nodules imbedded in limestone, not dissimilar to the flints in the Upper Chalk, or in distinct beds from one to five inches in thickness, which may be either independent of the beds of limestone, or form central masses with limestone above and below them. These chert beds occur throughout the Upper Limestone Series of the Irish Carboniferous, which has a thickness of from 600 to 800 feet; in places they constitute from one-tenth to one-fifth of the total mass of the rock; Professor Hull, however, estimates that they form almost a half or a third of the entire thickness. Accepting the lower estimate, the total thickness of the chert in the series would be from 100 to 150 feet.

In microscopic sections of specimens from every locality I visited sponge-spicules are present; they are more abundant in the beds of chert in which there is no apparent calcite, and the rock in many instances is filled with them. Further, in frequent instances the compact, dark chert-beds weather so as to form both on their upper and under surfaces a porous, siliceous, granular crust of a grey tint and harsh to the feel. This crust under favourable conditions can be seen to be composed of innumerable minute sponge-spicules, intermingled and, as it were, felted together. There is therefore direct and undisputable evidence that the silica in the chert is due to the accumulation and partial solution of these sponge-remains, and that it has not been derived as a direct *chemical* deposit from sea-water.

Through the courtesy of Professor Hull I examined under the microscope the rock-sections which he described and figured in his original paper, and though they had not been specially selected, there were sponge-spicules present in all of them; and I can fully confirm the published statement of Professor Sollas that in some, sponge-spicules make up the larger part of the chert. These sections make it evident that Professor Hull did not recognise the forms to be spicules, but that he regarded them as sections of crinoid structures.

During the last year I have studied the Carboniferous chert in the Yoredale Series of Yorkshire and North Wales, and I am now preparing a description of this rock. In all essential features it resembles the Irish chert, but the evidence of its derivation from sponge-spicules is far clearer, since the rock from these places has been less altered by fossilisation, and in many sections the chert is distinctly an agglomeration of spicules, whose forms are nearly as perfect as those of existing sponges. The beds of chert in Yorkshire are more continuous than those in Ireland; in some instances they form an uninterrupted series eighteen feet in thickness; this, however, is far exceeded by the beds in North Wales, where in borings they are proved to reach 350 feet in thickness without the intervention of limestones.

The organic origin of the Carboniferous chert, so strenuously denied by the

Director of the Irish Geological Survey, has been suspected by others, but hitherto satisfactory evidence of its real nature has not been brought forward. There can be no reasonable doubt that these chert beds result from an enormous and persistent development of siliceous sponges, and that they are chiefly composed of the detached microscopical elements of their skeletons.

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5. *On the Discovery of Carboniferous Fossils in a Conglomerate at Moughton Fell, near Settle, Yorkshire. By* ROBERT LAW, *F.G.S., and* JAMES HORSFALL.

After briefly noting the various exposures of the conglomerate, its unconformability with the Silurian rocks, its nature, probable age, and the circumstances which led to the discovery of fossils in it; the authors described the following section exhibited on the south-west side of Moughton Fell.

	Feet
a. Scar Limestone, of light grey colour and well jointed; layers very distinct in lower parts and almost horizontal, the genus *Bellerophon* being the commonest fossil in the lowest bed of this rock. Thickness from .	300 to 500
b. CONGLOMERATE.—Of a bluish-grey colour when newly fractured, and becoming reddish on exposure to the air. The fragments are rounded, angular, and sub-angular in form, consisting of slate, grit, flagstone, and vein-quartz, all apparently derived from Silurian rocks. Fossil shells and corals are common throughout the bed. *Bellerophon, Euomphalus, Syringopora,* and *Lithostrotion* are the prevailing genera. Thickness from .	1 to 12
c. Lower Silurian slates, of great thickness, having a N.E. strike and a dip of about 60°. The dip and cleavage appear to be on the same plane in this locality.	

The nature and the origin of the stones in the conglomerate were next pointed out; also it was shown that the portion of the bed in which fossils had been found was not more than 200 yards in length, and that it was thickest in the middle, thinning out to the east and west, and at one point could be seen merging into the overlying limestone.

The fossils collected from the conglomerate are as follows:—

Syringopora ramulosa.
Lithostrotion basaltiforme.
Euomphalus pentangulatus.
Cirrus, one species.
Sanguinolaria angustata.
Pleurotomaria, one species.
Orthoceratite, one species.
Rhynchonella acuminata.
Bellerophon tangentialis.
Bellerophon cornu-arietis.
Natica plicistria.
Natica lirata.
Natica elliptica.
Inoceramus, one species.
Spirifera, one species.
Pecten, one species.
Productus, three species.
Leptæna, one species.

In conclusion, attention was called to the probable method by which the conglomerate was formed.

FRIDAY, SEPTEMBER 2.

The following Reports and Papers were read:—

1. *Fifteenth Report on the Erratic Blocks of England, Wales, and Ireland.*

See Reports, p. 236.

2. *Note on a few of the many remarkable Boulder-stones to be found along the Eastern Margin of the Wicklow Mountains.* *By* Professor EDWARD HULL, *LL.D., F.R.S., F.G.S.*

Amongst the evidences of the former existence of an extensive sheet of ice descending from the Wicklow Mountains towards the shores of the Irish Sea is the occurrence of boulder-stones, chiefly formed of granite or granitoid gneiss, derived from the mountainous range to the westward, of a size seldom equalled—probably not surpassed—amongst the British Isles. As the Association includes in its labours the task of collecting details regarding erratic blocks, it may prove of interest if I record a few cases which have come under my own notice.

1. *The Mottha Stone.*—This remarkable boulder is perched on the summit of Cronbane Hill, above Castle Howard, and is a conspicuous object from all directions. It consists of grey granite, and rests upon Lower Silurian slate. Its dimensions are nearly as follows:—length, 14 feet; height, 9 feet; breadth, 9 feet. It contains about 35 cubic yards of matter, and its weight would be about 70 tons. From the site of the Mottha Stone, at a level of 816 feet above the sea, the eye ranges westward along the magnificent valley of Glenmalure, to the flanks of Lugnaquilla, at a distance of about ten or twelve miles, whence, as we may suppose, the granite block started on its journey. In its course it must have crossed the deep hollow of the Avonmore valley, which extends just below the feet of the observer transversely to the path of this remarkable erratic block.

2. *Castle Kevin.*—In the valley between Castle Kevin and Moneystown, where large boulders are numerous, there lies a block of granite, partially imbedded, of which the dimensions are:—length, 15 feet; breadth, 10 feet; height, 9 feet (imbedded portion—probably 3 feet—is not included in above). This block contains about 50 cubic yards of matter, and is about 100 tons in weight. The birthplace of this boulder was probably the mountainous tract about Mullaghcleevaun, 2,783 feet in height, lying at the head of the valley in which is situated the deep waters of Lough Dan, and it probably travelled a distance of eight or nine miles in an E.S.E. direction.

3. The last boulder-stone that I shall mention is the largest I have met with in co. Wicklow—perhaps in the British Islands. It stands behind a cottage by the roadside, near Roundwood Church, and is quite as large as the cottage itself, to which it forms a good protection from the storms descending from the mountains behind. This boulder consists of granitoid gneiss, resting on Lower Silurian slate and grit. Its dimensions are (q. p.):—length, 21 feet; breadth, 14 feet; height, 12 feet. Its form is somewhat oval, and it contains about 120 cubic yards of matter, and is about 240 tons in weight. The source of this block, which lies at an elevation of about 800 feet above the sea, was probably in the same locality with that of the Castle Kevin boulder, and the distance travelled was about six or seven miles.

The blocks above noticed, with many others of smaller size, do not belong to any of the local glaciers which once filled the valleys towards the close of the glacial epoch, and which have left numerous well-formed moraines in nearly all the principal valleys descending from the Wicklow range. They are to be referred, in all probability, to the earlier stage of intense glaciation, during which the whole district was covered with perennial snows and ice, moving eastward into the hollow now occupied by the waters of the Irish Sea.

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3. *The Terminal Moraines of the Great Glaciers of England.* *By* Professor H. CARVILL LEWIS.

The investigation here recorded is based upon the important principle that *every glacier at the time of its greatest extension is bounded and limited by a terminal moraine.* Supposed exceptions to this law in Switzerland and elsewhere had been studied by the author and found to be contrary to observed facts. Thus the ancient Rhone glacier, stated by Swiss geologists to be without a limiting moraine at the time of its greatest extension, was found to have one as distinct as those of

the Aare glacier, the Reuss glacier, or the Rhine glacier; and the prevalent idea of a 'first glacial epoch' in which the glaciers had no terminal moraines was also unsupported by the author's observations.

The great ice-sheet which once covered northern England was found to be composed of a number of glaciers, each of which was bounded by its own lateral and terminal moraines. These glaciers were studied in detail, beginning with the east of England, and the North Sea glacier, the Wensleydale glacier, the Stainmoor glacier, the Aire glacier, the Irish Sea glacier, and the separate Welsh glaciers were each found to be distinguished by characteristic boulders and to be defined by well-marked moraines. The terminal moraine of the North Sea glacier, filled with Norwegian boulders, may be seen in Holderness, extending from the mouth of the Humber to Flamborough Head; it consists of a series of conical hills enclosing meres. The moraine of the Stainmoor glacier, characterised by blocks of Shap granite, may be followed northward along the coast past Scarborough and Whitby; then west along the Cleveland Hills; then south again through Oulston to the city of York; then west to near Allerton, where the Stainmoor glacier is joined by the Wensleydale glacier—a fine medial moraine marking the line of junction. The Wensleydale glacier is characterised by boulders of carboniferous limestone and sandstone, and its lateral moraine is followed northward through Wormald Green, Markington, Fountains Abbey, and along the Permian outcrop to Masham, where it turns west to Wensleydale, passing Jervaulx Abbey, and running up the valley. North of Wensleydale the moraine of the Stainmoor glacier is followed through Richmond to Kirkby Ravensworth and westward to the mountains, where the glacier attained an elevation of 2,000 feet. Thus the Stainmoor glacier, a tongue of the great Irish Sea glacier, had been divided into two branches by the Cleveland Hills, one branch going south to the city of York, which is built on its terminal moraine, the other branch flowing out of the Tees and being deflected southwards along the coast by the North Sea glacier, with which it became confluent.

The Irish Sea glacier, the most important glacier of England, came down from Scotland, and, being reinforced by local ice-streams, and flowing southward until it abutted against the mountains of Wales, it was divided into two tongues, one of which flowed to Wellington and Shrewsbury, while the other went south-west across Anglesey into the Irish Sea. This great glacier and its branches are all outlined by terminal moraines, described in detail. A small tongue from it, the Aire glacier, was forced eastward at Skipton and has its own distinctive moraine. In the neighbourhood of Manchester the great moraine of this Irish Sea glacier may be followed through Bacup, Hey, Staleybridge, Stockport and Macclesfield, being as finely developed as the moraines of Switzerland and America. South of Manchester it contains flints and shell-fragments, brought by the glacier from the sea-bottom over which it passed. At Manchester the ice was at least 1,400 feet thick, being as thick as the Rhone glacier.

The great terminal moraine now described of the united glaciers of England is a very sinuous line, 550 miles in length, extending from the mouth of the Humber to the farthest extremity of Carnarvonshire, and, except where it separates the Welsh glaciers from the North Sea glacier, everywhere marks the extreme limit of glaciation in England, and is an important feature which might well hereafter be marked on the geological map of England.

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4. *On some important Extra-Morainic Lakes in Central England, North America, and elsewhere, during the Period of Maximum Glaciation, and on the Origin of Extra-Morainic Boulder-clay.* *By* Professor H. CARVILL LEWIS.

The lakes so characteristic of all glaciated regions are due to several causes. Some few are due to an actual glacial scooping out of the rock floor, many to an irregular deposition of the drift, by which former watercourses are obstructed, and still others to the terminal moraine or to the glacier itself. These latter, known as *morainic lakes*, may be divided into *inter-morainic lakes, moraine meres,* and *extra-*

morainic lakes, according to their position—back of, in, or outside—of the moraine. Extra-morainic lakes, if dammed up by the ice front, are temporary in character, disappearing with the retreat of the glacier; but, as they may be of enormous extent if the glacier is large, they may produce deposits of much geological importance. Instances of such lakes occur in Switzerland, and ancient examples occur as well in Northern Germany, Asia, North America, and Central England. They are to be expected wherever a glacier advances against or across the drainage of a country. Mr. Belt supposed that Northern Asia was covered by a lake of this character, caused by the Polar glacier obstructing the rivers flowing north.

In North America, where the terminal moraine has been accurately mapped for thousands of miles, deposits of boulder-clay and erratics occur outside of the moraine, and have been supposed to be due to an older glacier in the first glacial epoch. But the entire absence of striæ or of glacial erosion or moraines in this district proves that a glacier was not the agent of deposition. Nor are there any traces of marine life in the deposits. This extra-morainic boulder-clay is narrow in Pennsylvania, where the author had called it 'the Fringe,' but west of the Missouri is 70 miles wide; and in British America, between the great moraine called the 'Missouri Coteau' and the Rocky Mountains, is 450 miles wide and over 1,000 miles long. It only occurs where rivers had flowed *toward* the glacier, and is explained as the deposit of great temporary freshwater lakes dammed up by the ice-front, the erratics having been dropped by icebergs.

Similar deposits occur in England outside of the terminal moraine, and have been the subject of much discussion; being held by some to be a proof of marine submergence, by others to be the ground-moraine of a glacier. The 'great chalky boulder-clay' is the best known of these deposits. There are serious objections to the two theories heretofore advanced to explain this, whilst the hypothesis of extra-morainic fresh-water lakes, dammed up by the glaciers, is sustained by all observed facts. The most important of these lakes was one caused by the obstruction of the mouth of the Humber by the North Sea glacier, whose terminal moraine crosses that river at its mouth. This large lake reached up to the 400 feet contour line, and extended southward nearly to London, and westward in finger-like projections into the many valleys of the Pennine Chain. It deposited the 'great chalky boulder-clay,' and erratics were floated in all directions by icebergs. It was bounded in the Vale of York by the Stainmoor glacier, and Charnwood Forest was an island in it. At its flood period it overflowed south-westward by torrential streams into the Severn Valley and elsewhere, carrying the 'Northern Drift' into the south of England. Other glaciers in England were bordered by similar but smaller lakes wherever they advanced against the drainage. Three such lakes were made by the Aire glacier, the largest of them extending to Bradford. The Irish Sea glacier caused many similar lakes high up on the west side of the Pennine Chain, and at its southern end north of Wolverhampton. The overflow streams from the most southern of these lakes joined those issuing from Lake Humber in the Birmingham district, characterised by a 'commingling of the drift,' otherwise inexplicable. An examination of the supposed evidences for glaciation, and for a great marine submergence in Central and Southern England, shows that neither theory is sustained by the facts. Thus, the supposed striæ on Rowley Rag prove to be rootmarks or ploughmarks; those reported at Charnwood Forest to be due to running water or perhaps icebergs; the supposed drift on the chalk wolds to be a local wash of chalk flints; the high-level gravels on the Cotteswold Hills to be pre-glacial; the shells at Macclesfield, Moel Tryfan, and Three Rock Mountain to be glacier-borne, and not a proof of submergence; the drift on the Pennine plateau of North Derbyshire to be partly made by icebergs floating in Lake Humber, and partly a decomposed Millstone Grit or Bunter Sandstone; and the supposed Welsh erratics on Frankley Hill at a height of 800 feet to be in place and due to an outcrop of the paleozoic floor.

The conclusion that the glacial phenomena of England are due neither to a universal icecap nor to a marine submergence, but to a number of glaciers bordered by temporary fresh-water lakes, is in accordance with all the observations of the author in England and elsewhere.

5. *A comparative Study of the Till or Lower Boulder-Clay in several of the Glaciated Countries of Europe—Britain, Scandinavia, Germany, Switzerland, and the Pyrenees.* By HUGH MILLER, *F.R.S.E., F.G.S., Assoc. R.S.M.*

The sections of foreign till examined by the author occur chiefly in the neighbourhood of the Trondhjem Fjord, in Norway, at Berlin and Leipzig, in Germany, near the Lake of Geneva, in Switzerland, and in the valleys of the Pyrenees directly south from Pau, in southern France. In these countries and in Britain the till bears an identical character. It is not more variable throughout Europe than the author has found it to be in Scotland and northern England. On the basement-gneiss at Christiansund, in south-western Norway, it is the same as on the basement-gneiss of Sutherlandshire; in the great limestone valley of Eaux Chauds, in the Pyrenees, it is scarcely to be distinguished from the till of the limestone valleys of Yorkshire. In all the places mentioned (more doubtfully at Berlin and Leipzig) it bears the unmistakable character of a ground-moraine accreted under the direct weight of glacier-ice. Its essential character is that of a rude pavement of glaciated débris ground from the rocks over which the glaciers have passed, with its larger boulders firmly glaciated *in situ* on their upper sides in the direction of ice-movement, and with a tendency to the production of fluxion structure here and there in the matrix, due to the onward drag of the superincumbent ice. In mere indiscriminateness of composition (which is a character much emphasised by glacialists) the till is not to be distinguished from boulder-clays formed under berg- or raft-ice, such as the highest marine clays of the Norwegian coasts which are stuck promiscuously through with boulders derived from the glaciers of the interior. The glaciation of boulders *in situ* the author finds to be a crucial distinction; he readily detected this '*striated-pavement*' character in the tills of all the districts above mentioned except Leipzig and Berlin, where the boulder-clays resemble the upper boulder-clay (Hessle Clay) of the eastern seaboard of England and Scotland, and in the sections examined by him contained no large blocks.

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6. *Second Report of the Committee for exploring the Cae Gwyn Cave, North Wales.*—See Reports, p. 301.

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7. *On the Discovery and Excavation of an Ancient Sea-beach, near Bridlington Quay, containing Mammalian Remains.* By JAMES W. DAVIS, *F.G.S.*

During several years past occasional remains of animals, of older types than exist at present in the neighbourhood, have been found at the foot of the chalk cliff nearest Bridlington Quay. The remains, consisting of a part of an elephant's tusk, an antler of *Cervus megaceros*, bones of *Bison* or *Bos* and others, have generally been found after a more than ordinarily violent sea has washed down a portion of the clays and sand at the foot of the cliff. In May 1884 Mr. Clement Reid, of H.M. Geological Survey, had his attention drawn to the section by Mr. J. R. Mortimer, of Driffield, and he made a slight excavation[1] and obtained mammalian bones. During the spring of the present year the attention of the Council of the Yorkshire Geological and Polytechnic Society was drawn to the section, and it was decided to vote an expenditure of 10*l.* for the further exploration of the section. The consent of the proprietor, the Rev. J. Lloyd Greame, of Sewerby Hall, was readily and gracefully accorded, and Messrs. Lamplugh and Boynton, of Bridlington Quay, very kindly took charge of the work, and by their constant presence whilst the work was proceeding secured trustworthy and reliable evidence of the position and character of the beds and of the objects found in them.

The ancient cliff of chalk at the base of which the old beach is deposited ex-

[1] *Geology of Holderness*, &c., by Clement Reid, 1885.—Memoirs of the Geological Survey.

tends in an E. and W. direction, forming an angle of about 35° with the line of the present cliff towards Flamborough Head. The old cliff probably extended along the foot of the Wolds in a semicircle past Driffield to the Humber at Ferriby, and the whole of Holderness east of that line was under water. The old cliff at its termination seawards is fully 30 feet in height. Its surface is smooth, and the layers of chalk, ranging up to 2 or 3 feet in thickness, are rounded, exhibiting an appearance similar to a water-washed surface of mountain limestone. The present cliff offers a marked contrast; its surface, subject to constant denudation and weathering, exhibits a sharp and angular appearance without any of the polished convexity of the old one. The latter character is very suggestive, Mr. Reid considers, of the action of blown sand; and the presence of a large quantity of fine rounded sand in the section affords corroborative evidence of the correctness of the opinion.

The section exposed during the excavation is as follows:—

Boulder clay	
Blown sand	20 feet 0 inches
Semi-stratified marl sand and chalk wash .	4 ,, 6 ,,
Sea-beach of rounded pebbles of chalk . .	4 ,, 6 ,,

The thickness of the latter varies with the character of the chalk floor on which it rests. The latter is uneven and occasionally deeply hollowed. The old beach filled up the irregularities to a common level.

The lowest bed, which rests on a floor of denuded chalk, consists of well-rounded pebbles of chalk, many of them bored by Pholas, and a smaller number by Saxicava. Intermixed are a comparatively small number of fragments in a subangular condition, which have probably fallen from the cliff above and suffered less from denudation and attrition. It is marked by an entire absence of travelled rocks derived from the glacial clays which at present extend over the whole of the deposits comprising the old beach. The chalk pebbles are piled up under the cliff and gradually thin out as the mass recedes from it. The present beach is composed of similar chalk pebbles, but is readily distinguished from the old one by the presence of large numbers of stones and boulders of older rocks derived from the glacial clays which envelope the cliffs. In addition to the mollusca named above shells of Ostrea, Littorina, and Purpura have been found.

The next beds in the series are about 40 feet in thickness near the face of the chalk cliff, and extend about the same thickness for a few feet, after which they become attenuated and gradually disappear, giving place to 'blown sand.' The beds are characterised principally by alternations of sandy marl and chalk wash, which have been cemented together by the percolation of water; fragments of angular chalk frequently occur mixed in the mass.

The blown sand, which envelopes the beds last mentioned, extends far up the face of the cliff. It is fine, the grains vary little in size, and are well rounded. The sand appears to have been blown against the face of the cliff, and whilst thus having all the angles worn off has also been instrumental in reducing the rough angular surface of the chalk to its present smooth and mammilated appearance. The bed of sand, forming, with the beds below, a triangular mass, is enveloped on the side opposite to the cliff in a mass of stiff glacial clay, the lower purple boulder clay reaching from the summit of the cliff to the beach below. The general arrangement indicates a period, probably pre-Glacial, when the area under the old cliff was raised above the action of the waves, and the presence of land shells, of the genera Pupa and Helix, which have been found preserved in the cemented chalk wash clearly shows this to have been a land surface. The bones of mammals have also been found in considerable abundance in the same beds, as well as those below and in the quicksands above. With the advent of the Glacial era a great part of the sand would doubtless be removed, but that left was protected by the cliff, and the ice-sheet passed over it, leaving the whole covered with boulder clay on its retreat.

The number of animal remains found during the excavation has been both large and important; amongst others the teeth of *Elephas primigenius*, a vertebra,

probably the atlas, and several other bones of the same species; a jaw with teeth, as well as detached teeth, of rhinoceros, large jaw of Bos, and jaw with teeth either of wolf or dog; teeth of vole or rat, teeth and bones of bison. A tusk in a fragmentary condition may have been that of a walrus.

Bones of birds have been found, and jaws and vertebræ of fishes have occurred in the lower beds. The bones are in an extremely soft and friable condition, and it is only by the exercise of very great care that the pieces composing the bones were collected in a manner which will enable them to be pieced together again. The efforts in this direction made by both the directors is beyond praise, and the results amply repay the trouble taken. Mr. Lamplugh is preparing a detailed report on the excavation and the objects discovered, which will be printed in the 'Proceedings of the Yorkshire Geological and Polytechnic Society.'

SATURDAY, SEPTEMBER 3.

The following Papers and Report were read:—

1. *On the Discovery of the Larval Stage of a Cockroach*, Etoblattina Peachii *(H. Woodw.), from the Coal-measures of Kilmaurs, Ayrshire. By* HENRY WOODWARD, *LL.D., F.R.S., F.G.S.*

This interesting fossil is preserved in a small clay ironstone nodule, and measures 23 millimètres in length and 14 millimètres in breadth, and exhibits the minute head sunk in the rounded pronotum, a pair of rudimentary wing-covers, and a pair of rudimentary wings, a body with nine segments having broadly expanded free edges to the terga, like certain larval forms, but unlike the adult of modern cockroaches. The author compares this interesting Coal-measure insect with Goldenberg's *Blattina insignis,* from the Coal-measures of Saarbruck, and with *Leptoblattina exilis* (H. Woodw.), from the Staffordshire coalfield. Also with the larval stage of the living *Blabera atropos,* Stoll, from Brazil, with which it closely agrees, both in the character of the wings and the broad margins to the terga of the abdominal somites.

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2. *On a new Species of* Eurypterus *from the Lower Carboniferous Shales, Eskdale, Scotland. By* HENRY WOODWARD, *LL.D., F.R.S., F.G.S.*

From previous researches we were made acquainted with a remarkable *Eurypterus* from the Carboniferous Limestone series, of Kirkton, Bathgate, West Lothian, named *Eurypterus Scouleri* by Hibbert in 1836. Other doubtful species have been noticed from Cape Breton and from Nova Scotia, and one from the Lower Coal-measures of Darlington, Pennsylvania, U.S.A., discovered in 1881. These, with four Devonian and seventeen Upper Silurian forms, complete the known list of *Eurypteri.*

The present discovery introduces us to a specimen $5\frac{3}{4}$ inches broad by about 20 inches long. The hind segments are imperfect and the telson is wanting. The swimming feet were about 8 inches in length. The head was very rugose, and the anterior segments covered with strong pointed squamæ, like those of *E. Scouleri.* The eyes cannot be made out, and the swimming feet are not seen. This new type has been named by the author *Eurypterus scabrosus.*

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3. *On the Discovery of Trilobites in the Upper Green (Cambrian) Slates of the Penrhyn Quarry, Bethesda, near Bangor, North Wales. By* HENRY WOODWARD, *LL.D., F.R.S., F.G.S.*

Although the Cambrian rocks of Wales were long considered barren in all evidence of organic remains, the labours of the late Mr. J. W. Salter, Mr. T. Belt, Mr. David Homfray, of Portmadoc, but most of all those of Dr. Henry Hicks,

F.R.S., at St. David's and elsewhere, have added an extensive series of organisms to these lower rocks. The Longmynd group, which elsewhere had only yielded annelide burrows and a portion of a trilobite, had at St. David's furnished a sponge, two ostracods, six trilobites, two *lingulellæ*, and two thecæ.

The Menevian beds at St. David's have made known three sponges, one echinoderm, twenty-five trilobites, five pteropods, and three brachiopods. No fewer than twenty-five genera and eighty-five species of trilobites are now recorded from the Longmynds up to the Tremadoc slates. Dr. Hicks observes that the Longmynds have yielded a few indications of life in Shropshire and North Wales, but these beds require to be further explored.

The *first trilobite* in the green slates of Bangor was discovered by two workmen and recorded by Professor J. J. Dobbie, of the University College of North Wales, Bangor, on 5th August last. Two specimens have been obtained, the second by Professor Dobbie himself.

The most perfect is $3\frac{1}{2}$ inches long and $1\frac{3}{4}$ broad, and shows both the intaglio and relievo.

The margin of the head shield is rounded; the glabella has three lateral furrows; there are fourteen free thoracic rings and a short pygidium, consisting of about three coalesced segments.

After a careful comparison with *Conocoryphe*, *Olenus*, *Paradoxides*, *Angelina*, &c., the author concludes to place the Bangor trilobite in the genus Conocoryphe, and names it *Conocoryphe viola*.

Horizon: Upper Green Slates.

'Llanberis Grits and Slates,' Harlech and Longmynd Rocks.

Loc.: Penrhyn Slate Quarry, Bangor, North Wales.

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4. *Fifth Report on the Fossil Phyllopoda of the Palæozoic Rocks.*—See Reports, p. 60.

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5. *On the Mode of Development of the Young in* Plesiosaurus. *By* Professor H. G. Seeley, *F.R.S.*

This paper was descriptive of a specimen submitted to the author by J. F. Walker, Esq., F.G.S. It is a phosphatised nodule from the Lias of Whitby, measuring about 10 centimètres by 7 by 5. On its surface are four more or less complete specimens regarded as fœtal plesiosaurs, together with fragments of at least three others. They are remarkable for having the flesh mineralised with phosphate of lime, and still show many characters of the external form of the body, but slightly distorted by decomposition. Only one individual has the head preserved: its extreme length is about 14 mm. The nares are terminal like those of an emydian chelonian. The eyes look obliquely upward and outward. The superior aspect of the head behind the frontal bone is occupied by muscular substance. The skull rests on one side against the matrix, so that its transverse width is not clearly shown; but it was wider than the neck, and narrows in front of the orbit towards the nares, which curve a little downward. The eyes look obliquely upward and outward, and have a diameter of two millimètres. The neck has a length of 4·5 centimètres. Behind the head it is about four millimètres deep and as wide; it widens to a centimètre where the expansion takes place at the shoulders, and there the depth is about eight millimètres. A sharp median ridge down the middle of the neck divides its superior aspect into two oblique moderately convex surfaces. Other individuals show that this ridge was prolonged down the back and tail, but less elevated. The body is about as long as the neck. On the right side it has suffered some abrasion and injury in cleaning, and is not quite symmetrical, being a little larger on the left side. It is about 2·4 centimètres wide, convex from side to side, and less convex in length. The expansion from the neck is rapid, and attenuation posteriorly is marked, so that the body has a long egg-shape. The tail appears to be short and conical, and curves

rapidly downward in every specimen. The height of the body was not more than half its width. The limbs are imperfectly preserved. The distance between them on the left side is 2·4 centimètres. The anterior limb appears to be the larger. The entire length of the specimen is 12·5 centimètres.

This individual lies over the neck of another specimen which was larger, and appears to have measured fifteen centimètres without the head. It shows the fore limbs to have been very wide relatively to their length. The limb measured in the antero-posterior direction 1·1 centimètre at the junction with the shoulder on the right side; it is flattened, extended horizontally, imperfect distally, and curved somewhat backward, but evidently short as compared with the adult. The hind limbs of this specimen are not seen.

Other individuals are smaller, and have the body only about half as wide. They are very narrow in the anterior part of the body, and there appears to be only a slight budding of the fore limbs.

Hence the author regarded this specimen as showing that Plesiosaurus was viviparous, and that in one species from the Lias many were produced at one birth. The species was probably a long-necked one, and may have been *P. homolospondylus*, since the head in young animals is relatively large, and here it is $\frac{1}{9}$ the total length of the animal.

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6. *On the reputed Clavicles and Interclavicles of* Iguanodon. *By* Professor H. G. SEELEY, *F.R.S.*

The author showed by superimposing a figure of the reputed clavicle upon the bone figured by Mr. Hulke as clavicle and interclavicle of Iguanodon ('Quart. Jour. Geol. Soc.' vol. xli. pl. xiv.), that the supposed sutures are fractures, and that the supposed interclavicle has no existence, except as an ossification posterior to the reputed clavicles. Then it was urged that these bones are unparalleled by any vertebrate clavicles, while the reputed pubes of crocodiles and pre-pubes of other animals offer a more probable analogy. The ossification in front of the pubis in Ornithosaurs is of similar form in several genera; and in crocodiles the ossification of the fibrous extension which connects the reputed pubes with the sternal ribs would produce a bone like the supposed interclavicle of Iguanodon. Hence it was urged that these bones in Iguanodon are pre-pelvic, and the author identified them with the pre-pubic bones.

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7. *On* Cumnoria, *an Iguanodont Genus founded upon the* Iguanodon Prestwichi, *Hulke. By* Professor H. G. SEELEY, *F.R.S.*

This genus is named from Cumnor, the locality where the fossil was found. It is separated from Iguanodon by many characters, such as the different type of parallel ridging and coarser serration of the teeth. The vertebræ are relatively wider, the neural arch and centrum both being more depressed; the laminæ of the neural arch are very stout, and the neural canal very small; the sacral vertebræ are not anchylosed, are only four in number, and are convex on the ventral surface. The early caudal vertebræ are reduced in length, and have the neural arch small. The astragalus and calcaneum are separate. In these and other characters this Kimmeridge clay type differs from Iguanodon, and in some of them approximates towards Hypsilophodon and Mochlodon.

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8. *The Classification of the* Dinosauria. *By* Professor H. G. SEELEY, *F.R.S.*

The author discussed the structure of the animals named Dinosauria, and concluded that the group had no existence, the constituent animals belonging to two orders, which have no near affinity: one with a sub-avian pubis and ischium, the other with those bones sub-lacertilian.

The ORNITHISCHIA[1] is defined as having the ventral border of the pubic bone

[1] These groups are more fully defined in a communication to the Royal Society, read November 23, 1887.

notched out, so that one limb is directed backward parallel to the ischium, while the other limb is directed forward. The ilium has a slender prolongation in front of the acetabulum.

The SAURISCHIA [1] is defined by having the pubes directed forward with a median symphysis, but with no posterior limb to the bone. The anterior prolongation of the ilium has a vertical expansion.

SUB-SECTION C.

1. *La Calcédoine enhydrique de Salto Oriental (Uruguay) et son véritable gisement. By* Professor VILANOVA.

Le minéralogiste Haüy a nommé comme ça une variété qui forme de petites poches dans lesquelles a resté une partie de l'eau mère, résultat d'un geyserisme très actif, car il en reste encore même dans les eaux du Rio Negro, du Catalan et d'autres qui portent la silice en dissolution. Les premiers échantillons de cette curieuse variété américaine m'ont été adressés par un de mes compatriotes, D. Clemente Barrial Posada, établi depuis quelques années à Montevideo, mais sans rien me dire de son vrai gisement ; lorsqu'un un de mes amis, D. Manuel del Palacio, ayant résidé dans cette ville comme envoyé de notre gouvernement près le Président de la République, reçut comme un beau cadeau deux échantillons de la roche dans laquelle se trouvent les dites calcédoines, et m'en ayant offert un des exemplaires, je l'ai fait analyser micrographiquement par D. Francisco Guiroga, aide naturaliste très habile du Musée de Madrid, et voilà le résultat de cette étude. La roche, de couleur sombre, de structure compacte et assez lourde, contient de l'oligoclasse formant des macles selon la loi de l'albite, et celle de la pericline plus l'albite.

De l'augite en petits fragments irréguliers, gris violacé sale. Du verre jaunâtre, très abondant. De la magnetite en granules. De l'opale et zéolite en amygdaloïdes. On peut dire par conséquent, à juger par la facies du feldspath et par l'abondance de la silice, que la roche dans laquelle se trouvent les calcédoines enhydriques, c'est une andesite augitique tertiaire ou post-tertiaire.

On sait combien les restes du dinotherium sont encore rares, et pas trop étendues les limites de son aire de dispersion ; eh bien ! ses limites viennent d'être considérablement élargies, car dans la péninsule ibérique où aucune de ses espèces n'avait été auparavant trouvé, nous en possédons aujourd'hui au moins deux espèces, le D. giganteum, découvert près d'un village de la province de Valladolid nommé Fuensaldana, dans des couches calcaires un peu marneuses et blanchâtres, appartenant au grand dépôt tertiaire lacustre de la Vieille Castille. Ces restes consistent en une partie de la tête, la moitié gauche de la mâchoire inférieure, et un morceau d'une défense : à part il y a quatre molaires parfaitement conservées. Tous ces échantillons se conservent aujourd'hui dans mes collections paléontologiques du Musée de Madrid. L'autre espèce c'est le D. bavaricum, selon Gaudry, et d'après les indications du chanoine Almera, géologue distingué de Barcelone, il provient d'une mine de lignite qu'on exploite dans un village de la même province de la Catalogne.

Une troisième localité de la province de Huesca (Aragon) fut indiquée par un individu qui apporta au Musée de Madrid une dent du D. giganteum à vendre ; mais je craignis qu'il y eût fausse indication, et il pourrait bien se faire que l'échantillon provînt de Castille.

Mais laissant de côté ces doutes, au moins il est tout à fait certain, que deux espèces de dinotherium vécurent en Espagne à l'époque des grands lacs miocènes qui occupaient l'actuel territoire des deux Castilles et une partie de la Catalogne.

[1] These groups are more fully defined in a communication to the Royal Society, read November 23, 1887.

2. *On the Phyllites of the Isle of Man.* *By* Professor W. BOYD DAWKINS, *F.R.S.*

Professor Boyd Dawkins called attention to the slates of the Isle of Man, which present every gradation from the ordinary slate with minute crystals of mica, deposited in the planes of cleavage, to a twisted and highly altered rock, Phyllite, containing so much mica as to appear silky. This has been subjected to secondary cleavage (slip-cleavage of Bonney), which has resulted from a pressure which has broken through the original lines of cleavage. Wherever in the original slate a quartz vein has occurred, the friction between it and the softer Phyllite when the pressure was applied has caused the development of large flakes of mica, and in some cases of a fibrous hornblendic material. Both these are due to the local development of heat.

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3. *On Thinolite and Jarrowite.* *By* Professor G. A. LEBOUR, *M.A., F.G.S.*

The thinolite of Clarence King, from 'Lake Lahontan,' in Nevada, recently described by E. S. Dana ('Zeit. Kryst. Min.' Bd. xi. p. 285, and 'Bull. U. S. Geol. Survey,' vol. ii. No. 12), is regarded by the author as the same mineral species as Jarrowite, long since recorded from the alluvial beds of the river Tyne at Jarrow.

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4. *A Shropshire Picrite.* *By* W. W. WATTS, *M.A., F.G.S.*

In this paper the author described a variety of picrite which occurs in the Shelve and Corndon district of Shropshire. The rock has an ophitic structure, and contains olivine grains set in large plates of brownish augite A certain amount of plagioclase and magnetite are present, together with a smaller quantity of brown mica. The largest dike runs N.E. and S.W. from North Dysgwylfa farm to Shelve pool, but blocks of it are found widely scattered through the region, so that it is perhaps plentiful in the district. This dike crosses the direction of the intrusive andesites and dolerites described in the 'British Association Report for 1886,' and is the latest intrusion, so that it must be at least post-Silurian in age. It is sharply marked off from the other intrusive rocks by the abundance of olivine, a mineral scarce in, if not absent from, the other intrusive rocks. Such a well-marked rock type will be useful to those studying the Shropshire erratic blocks.

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5. *On the Mineralogical Constitution of Calcareous Organisms.* *By* VAUGHAN CORNISH *and* PERCY F. KENDALL.

INTRODUCTION.—In Dr. Sorby's presidential address to the Geological Society in 1879 it was stated that both Calcite and Aragonite occur in organic structures, and that Aragonite fossils are less stable than those of Calcite.

It appeared probable that carbonic acid has been the agent which effected the removal of the Aragonite, but we had found no published experimental data to show that it would remove Aragonite more readily than Calcite.

PART I.—*An account of the experimental evidence obtained as the cause of the inferior stability of Aragonite fossils as compared with those formed of Calcite, with observations on the geological conditions favourable to the removal of Aragonite fossils.*

It was pointed out by one of us[1] that those shells classed by Dr. Sorby as Calcite are characterised in the fossil state by a compact texture and by translucency, while the Aragonite shells are opaque and of a chalky appearance.

Experiment 1.—A Calcite and an Aragonite shell of about equal weight and surface were subjected to the action of carbonated water and then weighed.

Result.—The Aragonite shell lost between two and three times as much in proportion to its weight as did the Calcite shell, and it fell to pieces.

Experiments 2 and 3 were made upon *finely powdered* Calcite and Aragonite.

[1] *Geol. Mag.* Nov. 1883.

In No. 2 the pure crystallised minerals were employed, and in No. 3 powdered shells.

Result.—About equal quantities of the two substances were dissolved.

Conclusion.—That the instability of Aragonite shells, as well as their opacity, is due not directly to their mineralogical constitution, but to their structure.

The geological conditions favourable to the removal of Aragonite shells is found to be—

a. Enclosure in permeable beds.

b. Flow of carbonated water.

PART II.—*An account of the work done in following out the foregoing observations, and in the examination of certain organisms belonging to groups not yet classified according to their mineralogical constitution.*

The constitution of the shells, &c., mentioned hereafter, was ascertained by determination of the sp. grs.

The observations were made in following out indications obtained—

(1) From the known inferior stability of Aragonite shells.

(2) From the rule which appeared to hold with regard to the translucency of Calcite fossils and the opacity of those of Aragonite.

Gasteropoda.—Scalaria (fossil) sp. gr. 2·685 Calcite. *Murex tortuosus* (fossil) has thick opaque inner layer.

Sp. gr. 2·85; therefore probably mainly Aragonite. From a comparison of the Calcite layers of this shell and of *Purpura lapillus*, we are led to regard the crag *Purpura tetragona* as a variety of *Murex erinaceus.*

Tectura testudinaria (recent) sp. gr. 2·834. Fossil tecturæ have an *opaque* inner layer; therefore probably Aragonite.

Fusus.—The determination of three species confirmed the opinion expressed by one of us in the paper before cited.

F. antiquus,	sp. gr.	2·668	Calcite outer layer.
F. costifer	,,	2·88	Aragonite.
F. pyriformis	,,	2·95	Aragonite.
F. longævus	,,	2·89	Aragonite.

Cephalopoda.—Ammonites, from their appearance and mode of occurrence, are probably to be regarded as Aragonite, but the aptychi which are found well preserved with *casts* of Ammonites are translucent, and their sp. gr., 2·70, proves that they are Calcite.

Belemnites.—The guard has a sp. gr. of 2·67, and is Calcite. The phragmacone is not preserved in porous beds, and is opaque. The sp. gr. of a specimen infiltered, but not replaced by Calcite, was 2·75; we therefore consider it to be Aragonite.

Placophora.—Chiton (recent), sp. gr. 2·848. Aragonite.

Heteropoda.—Dolabella (recent), sp. gr. 2·859. Aragonite.

Lamellibranchiata.—Pecten opercularis (recent), sp. gr. 2·70. Calcite. *Pectunculus glycimeris* (recent), sp. gr. 2·845. Aragonite. *Artemis lentiformis* (fossil), opaque sp. gr. 2·84. Aragonite.

Hexacoralla.—All the corals examined by Dr. Sorby were mainly or entirely Aragonite. We examined one of the Upper Chalk corals, *Parasmilia centralis*, and found it to be translucent, and to have a sp. gr. of 2·7; therefore it is Calcite.

Polyzoa.—Dr. Sorby found many forms to be composed of Calcite with Aragonite, and supposed that the two substances were *mixed*; but the observations of one of us point to the conclusion that there is an *outer* layer of Aragonite.

Foraminifera.—Dr. Sorby classes these in his Calcite division; but we are led to believe that the Porcellanea are Aragonite. They are opaque in the fossil state, and, so far as we can ascertain, are not found in beds from which the Aragonite shells have been dissolved.

In Dixon's 'Geol. of Sussex,' 93 species and varieties of Foraminifera are recorded from the Chalk, and *only one Porcellanous form is mentioned*, and that without the specific name. Experiments upon the comparative solubility of the Porcellanea and Vitria confirm our impression.

Teredo Norvegica.—Teredo is regarded by Dr. Sorby as a typical Calcite shell;

but certain tubular fossils found by one of us in the crags, and which have been regarded as *T. Norvegica*, have the opacity characteristic of Aragonite; and upon this circumstance and peculiarities in its mode of occurrence the opinion was based that the reference of the form to Teredo had been erroneous. In this view the late Dr. Gwyn Jeffreys concurred. The fossil has a sp. gr. of 2·9, and is therefore composed of Aragonite. We offer no suggestion as to its affinities.

MONDAY, SEPTEMBER 5.

The following Papers and Reports were read:—

1. *On new Facts relating to Eozoon Canadense.* *By* Sir J. William Dawson, *LL.D., F.R.S.*

For several years no new facts respecting the Canadian *Eozoon* have been published, though there has been some discussion on the subject abroad. In so far as the author is concerned, this has arisen from the circumstance that the late Dr. Carpenter had in preparation an exhaustive memoir, for which Canadian material was being supplied, but which was unfortunately left unfinished at his death. The material collected for this has now been placed at the disposal of Prof. T. Rupert Jones, F.R.S., and in the meantime the present note is intended merely to direct attention to some new facts recently obtained. These are stated under the following heads:—

1. *Form of Eozoon.*—This has been definitely ascertained to be normally inverted conical or broadly turbinate, except where several specimens have become confluent, or where rounded masses have been based on some foreign body.

2. *Pores or Oscula.*—The larger specimens are traversed by cylindrical or long conical vertical openings, around which the laminæ, becoming confluent, form an imperfect wall.

3. *Beds of Fragmental Eozoon.*—A large series of facts has been obtained to show that considerable beds of Laurentian limestone are composed of fragments of this kind.

4. *Veins of Chrysotile.*—It is shown that these are true aqueous veins of late origin crossing the beds, and the specimens of Eozoon as well. The true nature of the so-called proper wall is defined as distinct from these veins.

5. *Nodular Serpentine.*—Nodules and grains of serpentine abound in the Laurentian limestones of the Grenville band. Instances are referred to where these nodules surround, or are attached to, specimens of *Eozoon.*

6. *State of Preservation.*—The importance of dolomite in reference to this is noticed, also the different varieties of contemporaneous aqueous serpentine and the agency of white pyroxene.

7. *Other Laurentian Organisms.*—Cylindrical or conical bodies resembling stems of plants, with obscure radiating structure, have recently been found associated with the Laurentian apatite. They may possibly have been organisms allied to *Archæocyathus.*

8. *Cryptozoum.*—Certain relations of this new Cambrian fossil to *Eozoon* are pointed out, and the occurrence of Laurentian specimens hitherto referred to *Eozoon* but which resemble *Cryptozoum.*

9. *Laurentian Stratigraphy.*—Facts are referred to indicating the continuity and definitely stratified character of the beds in the Middle and Upper Laurentian of Canada.

10. *Imitative Forms.*—A variety of laminated rocks and minerals which had been mistaken for Eozoon were referred to. Their description in more detail will be found in forthcoming memoirs of the Peter Redpath Museum.

Photographs illustrating some of the more important structures referred to accompany the paper.

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2. *Gastaldi on Italian Geology and the Crystalline Rocks.*[1] *By* T. STERRY HUNT, *LL.D., F.R.S.*

The author recalled the fact that, in discussing in 1883 the geological relations of serpentines, he had maintained that, although not confined to Archæan rocks (in which they are found at various horizons) those of Italy, believed by some geologists to be in part of Tertiary age, are, so far as his studies go, wholly Archæan, in accordance with the views set forth by Gastaldi. He had in the paper in question which, revised and augmented, forms Chapter X. of his Mineral Physiology and Physiography (Boston, 1886) resumed at some length the work of this eminent geologist, left incomplete by his premature death in January 1879, and had given a list of his printed papers on Alpine geology so far as known to the writer. He had then proceeded to review the work of various other Italian geologists who had maintained the Eocene age of certain serpentines in that region, and from his own observations of certain localities in the Apennines of Liguria, and of Prato in Tuscany, endeavoured to show that the serpentines and other rocks of the ophiolitic group in these localities existed in their present condition in the seas in which were deposited the Eocene strata, which latter, by subsequent terrestrial movements, had been disturbed, broken, and even inverted, so as to seem to pass beneath the ophiolites. The indigenous and neptunian character of serpentines, maintained on stratigraphical grounds by Emmons, Logan, and the writer in North America, was not only held by Gastaldi and Delesse, but is taught by Lotti, by Stapff, and by Dieulefait in emphatic terms, while the plutonic hypothesis of their origin has been so far modified by its modern Italian advocates that they now suppose the serpentines due to submarine eruptions of a hydrous magnesian mud, which subsequently consolidated into serpentine and even into chrysolite. It is difficult to admit any other than a neptunian origin for the stratiform ophicalcites into which the massive serpentines often graduate.

While the writer's conclusions as to the localities named were thus in perfect accord with the views of Gastaldi, he was not then aware that this geologist had ever examined them. In July 1878, however, while in London, the writer received from Gastaldi a long epistle dated at Turin, July 20, and after perusing the first and last pages, and answering what was of immediate moment, laid it aside, unread. The letter was then by an accident mislaid, and only recovered during the present year. In a translation of this letter, which is now given, Gastaldi presents (ostensibly for the International Geological Congress of 1878) a brief summary of the views set forth at length in his published papers and in the writer's volume above named. He further adds that he had then just returned from a special study of the ophiolites of the Ligurian Apennines and of those of Prato, and had found convincing evidence that these were, like those elsewhere examined by him, protruding portions of the ancient *pietre verdi* zone, identical with that of the Alps, from which the Apennines cannot be distinguished either geologically or geographically.

The vast series designated by him as the *pietre verdi zone* overlies, according to Gastaldi, the ancient central or primary gneiss (generally granitoid, but including quartzites and crystalline limestones with graphite, &c.), and has a thickness of many thousand metres, embracing three subdivisions. The lowest of these, sometimes called by him the pietre verdi proper, includes serpentines, diorites, euphotides, chloritic schists, &c.; the second is designated by him recent gneiss and granite with mica-schists and hornblendic rocks; while the third consists in great part of soft argillaceous or lustrous schists, with included quartzites, marbles, statuary, and banded dolomites, and occasionally also serpentines, the presence of which led Gastaldi to include it with the two preceding subdivisions in his great pietre verdi zone; a name which the present writer, with Neri and others, would restrict to the lower subdivision, regarded by him as the equivalent of the Huronian of North America; the underlying or central gneiss being the Laurentian; the recent gneiss and mica-schist, the Montalban or White Mountain series, and the upper subdivision, the Taconian or Lower Taconic of North America; the wholly

[1] Published *in extenso* in the *Geol. Mag.* for December 1887.

distinct Upper Taconic being an uncrystalline series of fossiliferous Cambrian strata.

The writer in this connection recalled the work of Neri, Gerlach, and others in the western Alps, and that of Von Hauer and his associates in the Lombardo-Venetian Alps, where the same distinction of the true pietre verdi zone between the ancient gneiss below and the recent gneiss above had, unknown to him, been pointed out by the Austrian geological survey two years before the present writer in 1870 defined and named the younger gneissic series in North America. The absence of the true pietre verdi series in some localities, alike in the Alps and in North America between the older and younger gneisses was noted, as well as the existence of apparent discordances between each one of the four great divisions of Archæan or pre-Cambrian crystalline rocks above named.

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3. *Elements of Primary Geology.*[1] *By* T. STERRY HUNT, *LL.D., F.R.S.*

The author, after recalling his classification of original or non-clastic rocks into Indigenous, Endogenous, and Exotic masses, based on their geognostic relations, gives in a concise form his theory of the genesis of these various groups of rocks, as taught more at length in his recent volume entitled 'Mineral Physiology and Physiography.' The superficial portion of a cooling globe, consolidating from the centre from a condition of igneous fusion, he conceives to have been the protoplasmic mineral matter, which, as transformed by the agencies of air, water, and internal heat, presents a history of mineralogical evolution as regular, as constant, and as definite in its results as that seen in the organic kingdoms. This great transformation involves a series of processes, which include, (1) the removal from the protoplasmic mass, through permeating waters, heated from beneath, of the chief elements of the great groups of indigenous crystalline and colloidal rocks, by what he has called the crenitic process; (2), the modification of the residual portion by this lixiviation, which removes silica, alumina, and potash, and, by the intervention of saline waters, brings in additional portions of lime, magnesia, and soda; (3) the partial differentiation by crystallisation and eliquation, of portions of this more or less modified residue, giving rise to the various types of plutonic rocks. The direct and indirect results of subaerial decay through atmospheric agencies, and those of the products of organic life, are also considered. From the operation of all these processes result progressive changes in the composition alike of plutonic and of indigenous rocks. The endogenous rocks or veinstones are, like the last, of crenitic origin, and may be granitic, quartzose, or calcareous in their characters.

The author next considers the conditions of softening and displacement of indigenous rocks which permit them to assume in many cases the relations of exotic rocks, and to become extruded after the manner of lavas, as seen in the case of trachytes and many granite-like rocks. Such masses he designates pseudoplutonic. With these are often confounded the endogenous granitic veinstones, which were formed under similar chemical conditions to the indigenous granites. Masses alike of indigenous, endogenous, and exotic rocks may also become displaced, not through softening, but by being forced while in a rigid state through movements in the earth's crust, among masses softer and more yielding than they.

The author also considers the fluxional structure seen in plutonic and pseudoplutonic eruptive masses, which has led some theorists to regard these as of aqueous origin, and others to maintain that the crenitic stratiform masses themselves are of plutonic origin; two opposite errors which vitiate much of our geological literature.

The crenitic process, by removing from beneath what was the original surface of deposition, the vast amount of material which forms alike the indigenous, the endogenous, and the pseudoplutonic rocks, has effected a great diminution in volume in the protoplasmic mass, besides that due in later times to extrusion of plutonic matter itself. This decrease in bulk of the underlying stratum was a potent agent in producing the universal corrugation of the earlier crenitic rocks, and the frequent discordances observed among them.

[1] Published *in extenso* in the *Geol. Mag.* for November, 1887.

The author considers further the gradual diminution of the crenitic process seen in the later periods of Archæan time, and its feebler manifestations in Palæozoic and more recent ages down to the present. He notes, moreover, that as the result of geographical changes, erosion and partial deposition alike disturbed the succession of the later groups of crenitic rocks, none of which can claim that universality and uniformity which belong to the oldest known group, the fundamental granitoid gneiss.

The author concludes with a brief sketch of the great divisions of the indigenous crenitic rocks recognised by him, from the most ancient granitic substratum to the Taconian series, which appears to be the last of the characteristically crystalline indigenous groups, it being, so far as known, succeeded directly by the uncrystalline Cambrian, or the equally uncrystalline Keweenian, which may not, improbably, be itself included in the lower part of the Cambrian series.

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4. *Preliminary Note on Traverses of the Western and of the Eastern Alps made during the Summer of* 1887. *By* Professor T. G. BONNEY, *D.Sc., LL.D., F.R.S., F.G.S.*

The first traverse was made along the line of the Romanche from near Grenoble to the Col du Lautaret, and thence by Briançon over the Mont Genèvre and the Col de Sestrières to Pinerolo at the edge of the Italian plain. The second went from Lienz, across the central range of the Tyrol to Kitzbühel, and the rocks of this range were also investigated at other places. During both traverses the author had the advantage of the assistance of the Rev. E. Hill, who had accompanied him on a similar journey in 1885.

The results of their examination fully confirm the views already expressed by the author as to the nature and succession of the crystalline rocks of the Alps.

(1.) The lowest group consists partly of modified igneous rocks (which indeed occur at all horizons), partly of gneisses of a very ancient (Laurentian) aspect.

(2.) The next group, up to which there seems a gradual passage, consists mainly of more friable gneisses and moderately coarse mica-schists (Lepontine type). This group is commonly less fully developed in the above districts than in the Central Alps, having probably been removed by very ancient denudation.

(3.) The third group has an enormous development. It forms a large part of the Cottian and Graian Alps, and it flanks the central axis of the Eastern Alps on both sides, often passing beneath the ranges of secondary strata which here form the northern and southern ranges. It has been traced almost without interruption from east to west for more than fifty miles on the southern, and eighty on the northern side of the central range. It has a very close resemblance in all respects to the uppermost group of schists in the Central Alps, found to some extent in the Lepontine and yet more largely in the Pennine Alps, and the author fully agrees with the Swiss and Austrian geologists in regarding it as in the main a prolongation of the same series. It is characterised especially by rather dark-coloured mica-schists, often calcareous, sometimes passing into fine-grained crystalline limestones, with occasional intercalated chloritic schists, especially in the lowest part and with (rarely) quartz schists.

(4.) The Carboniferous and Secondary strata infolded or overlying in the Western Alps section, and the Palæozoic (? Silurian) and Secondary strata succeeding the metamorphic rocks in the Eastern Alps, are comparatively little altered, and are each readily to be distinguished from the above.

(5.) The succession of strata in the third group is inexplicable, unless it be due to stratification; in the second this explanation appears highly probable, and in the first not more difficult than any other.

(6.) As groups of rocks with marked lithological characters occur in like succession over a mountain chain measuring above 400 miles along the curve, and sometimes at distances of 40 miles across it; as these groups correspond with rocks recognised as Archæan elsewhere, which exhibit like characters and sometimes a like order of succession, the author thinks a classification of the Archæan rocks by

their lithological characters (using the phrase in a wide sense), may ultimately prove to be possible.

(7.) The views already expressed by the author as to the distinctness of cleavage-foliation and stratification-foliation have been fully confirmed by the examination of the above districts. He believes that the failure to recognise this distinction is the cause of the contradictory statements with regard to the relation of foliation and bedding which have been made by so many excellent observers, and lies at the root of much of the confusion which exists on the subject of the so-called metamorphic rocks.

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5. *Some Effects of Pressure on the Sedimentary Rocks of North Devon. By* J. E. Marr, *M.A., F.G.S.*

The structures described in this paper are mainly seen in the Ilfracombe division of the Devonian system, as exposed near the bathing-place at Ilfracombe. The rocks there consist of argillaceous beds with thin bands of grit and crinoidal limestone; these harder beds are folded into a series of small sigmoidal folds, which form portions of similar larger folds. When the middle limb is replaced by a fault, the cores of the folds remain as 'eyes' of limestone or grit, and these 'eyes' have undergone further modification, having been pulled out into thin lenticular masses. In this way we have all the mechanical structures of a true schist produced (including the apparent false bedding), the rock now consisting of clay-slate with alternating folia of grit or limestone, or both.

Quartz veins are folded in a similar way to that described above, and the final result of this folding appears to be the production of a rock consisting of alternating clay-slate, limestone, and quartz folia.

Every stage of the process is seen in the case of the limestone 'eyes.' The cores of limestone when not dragged out have their component crinoid stems pressed into polygons, which have been formed in the way described elsewhere by Dr. Sorby. When the limestone is pulled out the stems are separated, as in the case of the belemnites figured by Heim, and the intervening portion is filled with calcite.

In this neighbourhood, then, we find sedimentary rocks presenting all the mechanical peculiarities of normal schists, without any great amount of chemical change.

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6. *Report of the Committee appointed to investigate the Microscopical Structure of the older Rocks of Anglesey.*—See Reports, p. 230.

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7. *Notes on the Origin of the Older Archæan Rocks of Malvern and Anglesey. By* Charles Callaway, *D.Sc., F.G.S.*

The author had recently communicated to the Geological Society of London a paper in which he contended that certain crystalline schists of the Malvern Hills had been formed from igneous rocks. This conclusion was now extended to all the foliated rocks of the district. The metamorphism was *zonal*, the schistosity being usually confined to bands, which occurred most frequently where the rocks were interlaced with veins. The most important shear-zones were those in which diorite was penetrated by granite-veins. The following were the principal changes normally observed in approaching a shear-zone:—

(1) The rock acquired a parallel structure.

(2) This change was often accompanied by an apparent corrosion of the hornblende and felspar, numerous perforations appearing in the crystals, and their margins presenting curvilinear outlines. This effect seemed due to loss of bases, since it was attended by a corresponding development of quartz.

(3) The hornblende was replaced by black mica, the necessary potash being presumably derived from the felspar of the adjacent granite-veins, which were often extremely quartzose.

Within the zone, folia of quartz-felspar (the compressed granite-veins) alternated with the dioritic material. By further loss of bases the ultimate product was sometimes a quartzose gneiss or even a gneissoid quartzite.

The same principles were found to be on the whole applicable to the Gneissic Series of Anglesey; but in that area the earth-pressures were greater and more uniformly distributed, so that contortion was excessive and the bands of non-schistose rock were in smaller proportion. Diorite was modified into hornblendic and chloritic schists; or, in the vicinity of granite-veins, into mica-gneiss. Felsite passed into mica-schist. Other changes were not yet worked out.

No limestone was known in the Malvernian rocks, but calcite-veins, when abundant, were associated with rotten ferruginous schists. In Anglesey the crystalline limestones were in lenticular masses, and were overlain by rotten schists intermixed with quartzose bands. It seemed probable that these limestones were endogenous deposits derived from the decomposition of the adjacent rocks.

In the transformation of the igneous rocks into schists, the hornblende and felspars were converted into black and white micas, quartz, chlorite, epidote, sphene, garnets, and iron-ores. Such profound chemical changes suggested that the view of metamorphism here advocated should be called the *Chemico-mechanical* theory.

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8. *The Origin of Banded Gneisses.* *By* J. J. H. Teall, *M.A., F.G.S.*[1]

The author first discussed the meaning of the term gneiss. This term was generally understood to connote a more or less foliated rock of granitic composition. Dr. Lehmann had proposed, however, that it should be used in a structural sense only, as meaning a more or less foliated plutonic rock. He would thus speak of granite-gneiss, diorite-gneiss, and gabbro-gneiss. The author called attention to specimens illustrating gneissic structures in acid and basic plutonic rocks. When various examples of gneissic rocks—that is, rocks of the composition of plutonic igneous rocks but possessing parallel structures—were compared, two types of parallel structure might be recognised; the one characterised by a parallel arrangement of the constituents, the other by an arrangement of the constituents in bands of varying mineralogical composition; thus, bands having the mineralogical composition of a diorite frequently alternated with others having the composition of granite. He proposed to discuss a possible mode of origin for the banded gneisses of the latter type. It was now admitted that those of the former type were largely due to the plastic deformation of masses of plutonic rock either during or subsequent to the final stages of consolidation.

Many observers were, however, still inclined to believe that those of the latter type could only be accounted for by supposing that the original materials had accumulated by some process akin to sedimentary deposition. Now a possible mode of origin for these could be found if we could show: (1) that plutonic masses are liable to vary in composition, and (2) that such masses are occasionally deformed either during or subsequent to their consolidation. Scrope long ago proved that the laminated structure of certain volcanic rocks (liparites) is due to the plastic deformation of heterogeneous masses of acid lava. Any heterogeneous lump if deformed into a flat sheet will show laminated or banded structures, because each individual portion must of necessity take the form of the entire mass. Scrope not only proved this, but also called attention to the similarity between the structures of acid lavas and those of gneisses and schists. (*Geology of Ponza Isles,* 'Trans. Geol. Soc.' 2nd ser. vol. ii. p. 228.)

The author then proceeded to refer to illustrations of the fact that plutonic masses do vary in composition. He referred to the so-called contemporaneous veins, which are often more acid, and to the concretionary (?) patches which are often more basic in composition than the main mass of the rock with which they are associated. He also referred to cases in which granite and diorite may be seen to vein each other in the most intricate manner, and especially drew attention to photographs taken at the Lizard last year illustrating this feature. If complex

[1] Printed in full, with illustrations, in *Geol. Mag.* for 1887, p. 484.

masses of the kind referred to were deformed after the fashion of the acid lavas described by Scrope, then banded and puckered gneissic rocks would necessarily result. He then showed that in the Lizard district the banded rocks of Prof. Bonney's 'granulitic series' were continuous with masses in which granitic and dioritic rocks could be seen to vein each other in the most intricate manner, and that the constituent bands of the granulitic series were composed of rocks petrologically identical with those of the igneous complex. He did not mean to imply that the deformation was connected with the intrusion of the plutonic masses. He was rather inclined to regard it as due in the majority of cases to mechanical forces acting posterior to consolidation. The uncertainty which might exist as to the precise conditions under which the deformation was affected did not invalidate the main conclusion, which was that a banded structure in rocks having the composition of plutonic igneous rocks was no proof that the latter were not of igneous origin.

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9. *On the Occurrence of Porphyritic Structure in some Rocks of the Lizard District. By* HOWARD FOX *and* ALEX. SOMERVAIL.

Professor Bonney has described a porphyritic diabase which is seen on the shore at Polpeor, involved in micaceous and hornblendic schists. The authors have traced this rock further, and have recognised a porphyritic structure in many dykes and intrusions along the coast which cut through the serpentine, and also in the darker bands of Professor Bonney's 'granulitic group and in the actinolitic schists west of Lizard.'

Descriptions of these various localities were given and illustrative specimens were exhibited. The crystals of felspar are found to be most numerous in those rocks which lie in the closest proximity to the gabbros and serpentine. They have their long axes at various angles, and are mostly small except at Parn Voose, Cavouga, and Green Saddle. The felspathic and hornblendic lines often circle round the crystals.

Without discussing any theory as to the true nature and origin of the whole of the schists, the authors think that the porphyritic structure so prevalent in the dark bands of the 'granulitic group,' in many of the micaceous and other rocks, as also in the later intrusions cutting the serpentine, indicate an igneous origin for many rocks hitherto regarded as schists.

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10. *Some preliminary Observations on the Geology of Wicklow and Wexford. By* Professor SOLLAS, *LL.D., D.Sc.*

I. *Pre-Cambrian Rocks.*—The existence of these is, as yet, by no means demonstrated: the grey gneisses of the Greenore-point district closely resemble the corresponding rocks of Anglesey, as Dr. Callaway has pointed out, and are possibly Archæan. The asserted presence of Archæan rocks in the Aughrim section cannot be substantiated. Those regarded as Archæan are crushed igneous rocks, some hornblendic and others felspathic: the latter present themselves as 'augen-schists.' The Howth series is represented in the Carrick district, and in that of Wexford and the Forth Mountains, as well as elsewhere; it differs from the series exposed in the cliffs of Bray, but is so closely united with the latter that till further evidence is forthcoming the author would regard the two series as forming parts of the same system.

II. *Cambrian Rocks.*—Of late attention has been directed to the Cambrian quartzite, some authors asserting that it has been formed as a deposit from mineral springs, others that it is to be regarded as intrusive in the same sense as an admitted igneous rock. Examination under the microscope demonstrates that in all cases it is merely a somewhat altered grit; its intrusive appearance may result from its behaviour during the folding of the country: the softer argillaceous rocks may have flowed out in lines at right angles to the direction of pressure, the harder quartzites may have been broken across the line of flow into masses of various dimensions, and

the softer rocks would then have been forced in between their ends. In this way some of the thinner beds of quartzite have been converted into lines of boulders, *ex. gr.* at Howth.

III. *Ordovician.*—The unconformity between this system and the Cambrian, discovered by Jukes, is confirmed; on the south side of the Cambrian masses of Carrick the Ordovician slates are partly composed of fragments of green and grey Cambrian slates. The distinction between the Cambrian and Ordovician rocks as mapped by the Survey necessarily depends in most cases on differences of colour, the Ordovician being usually, but not always, blackish in tint; it is obvious, therefore, that considerable room exists for error. These rocks are profoundly modified on approaching the great granite mass which extends throughout the districts; the black slates and grits become lustrous with mica at a somewhat greater distance from the granite than is indicated on the Survey maps, near Glendalough, for at least half a mile farther from it. On approaching the granite closer, well foliated andalusite-, garnet-, and mica-schists appear, the foliation corresponding usually with the bedding planes, though these are folded upon themselves again and again. Never, however, is a schist produced which by any possibility could be mistaken for an Archæan rock. As in Wales so in this district the Ordovician are distinguished by a profuse development of igneous rocks; some of these are contemporaneous, some intrusive, nearly all show signs of having been subjected to extreme pressure; ash-beds are naturally converted into excellent slates, but flows and dykes are usually also rendered schistose for a variable distance from their margins, a central core remaining unaltered and thus affording a means of distinguishing in the field between an ash and an originally solid couleé or dyke.

IV. *The Granite.*—Notwithstanding the somewhat positive assertions which have been made as to the metamorphic nature of the granite, which extends for a distance of sixty-five miles from north to south, and from eight to fifteen from east to west, its intrusive character can be readily demonstrated; not only is the junction with the adjacent schists invariably well defined, without even the suggestion of a passage between the two, but the granite frequently sends branching and anastomosing veins into the surrounding rocks, and includes flame-like fragments of them; the reason why a metamorphic origin has been so strenuously maintained for this granite in particular is probably due to the fact that it shares the nature of a schist near the junction in so far that it possesses schistosity, the planes of schistosity in both the granite and the schist having the same direction; it need scarcely be added that this structure is the result in both cases of 'crush,' the abundant slicken-sided surfaces traversing the gneissose granite and its minute structure as seen under the microscope prove so much. Some granite which is not apparently crushed also exhibits foliation, but of a different character, resulting from an arrangement of the constituent mica in parallel planes; these planes also are parallel to the foliation of the adjacent schists; this would seem to indicate that the pressure which folded the country was beginning to act before the granite had everywhere solidified. Examples of this kind of foliation are exceedingly common around the northern end of the granite district, but it dies out towards the interior.

V. *Epoch of Folding.*—The folding of the Ordovician, as proved by the marked discordance between its strike and that of the succeeding Upper-old-red Sandstone or basal Carboniferous beds, took place before the Carboniferous system period. The intrusion of the granite was post-Ordovician and pre-Carboniferous, and its crushing and foliation occurred within the same interval.

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11. *On Archæan Rocks.* *By* G. H. Kinahan, *M.R.I.A.*

In this communication is given a short description of the American (Dominions and States) Archæan rocks, special attention being directed to the characteristics insisted on by such American authorities as Dana, le Conte, Selwyn, &c., the most important being the records, always found in America, of a vast lapse of time between the accumulation of the Archæan rocks and the subsequent deposition of the later rocks. The supposed Archæans in England are briefly referred to, and it is

pointed out that the British School of Archæanites seem for the most part to rely nearly altogether on lithological characters.

The Irish rocks are specially mentioned, and it is shown that *nowhere in Ireland are there records of a great lapse of time between the deposition of the supposed Archæan and that of the later rocks;* but, on the contrary, one group merges into the other, or is lithologically more or less similar, or is petrologically one and the same group, as rocks that in one place are classed as Archæans have in another place their equivalents classed as Ordovicians. Also the boundaries of the supposed Archæans are so obscure that they have continually been changed like the rolling fences of the farms adjoining a common, being pushed backward and forward to suit the fancy of a moment; yet prior to each of these changes it has been confidently affirmed that such lines of boundary mark a double hiatus, the rocks on one side being undoubtedly Archæans and those on the other the equivalents of the Ordovicians.

The true unconformable boundary in the province of Ulster for the most part is ignored, and, as it suits the fancy, some of the rocks below it may be or may not be included in the Ordovicians.

It was also pointed out that Drs. Callaway and Hull are the great advocates of the existence of Archæan rocks in Ireland, but as doctors' evidence nearly invariably differs, these doctors do not agree, as whenever one of these eminent observers says the rocks are Archæan, the other says they are not, neither of them agreeing in any place. It is therefore suggested that as such eminent observers disagree ordinary geologists may toss up to know in what age the GREAT ARCHITECT originally intended to place the rocks.

SUB-SECTION C.

1. *Recent Researches in Bench Cavern, Brixham, Devon. By* WILLIAM PENGELLY, *F.R.S., F.G.S.*

As long ago as 1839 the workmen in a limestone quarry on the southern shore of Torbay, and adjacent to the town of Brixham, laid bare at the back of the quarry the greater part of a vertical dyke composed of red earth and angular pieces of limestone. The quarrying operations, then discontinued, were resumed in 1861, when the entire dyke was disclosed, and among the materials of an incoherent part of it which fell down were found some hundreds of osseous remains, including skulls, jaws, teeth, vertebræ, portions of horns, bones, and pieces of bones —identified by Mr. W. A. Sanford, F.G.S., as relics of the cave-hyæna, wolf, fox (two species), bear, wild-bull, reindeer, hare, and arvicola (two species). The hyæna was by very much the most prevalent form; but there was nothing indicating that he found an habitual home there—not a coprolite was met with, nor was there a single bone scored with his teeth-marks, or broken after any of his well-known modes. The entire absence of anything betokening the existence of man was equally marked. It must be remembered, however, that the finds then met with were all from a mass of heterogeneous materials which had filled a fissure nowhere more than two feet wide and in places not more than a very few inches—not from a cavern in the proper sense of that term.

Adjacent to the left bottom corner of the dyke was the mouth of a low narrow tunnel, having a floor of stalagmite and extending into the hill to an unknown distance, but certainly upwards of thirty feet. The proprietor of the quarry declined to allow any scientific investigations to be made, stating that he meant to make such researches himself, but this was never done.

In September 1885, Mr. W. Else, Curator of the Museum of the Torquay Natural History Society, obtained permission from the gentlemen into whose hands the property had passed, to make such explorations as he might find desirable both in the dyke and in the tunnel; and from that date he has spent on the work all the odds and ends of time he has been able to command. His more recent researches have been mainly carried on in the tunnel, where he found the stalag-

mite floor, from six to twelve inches thick, formed on a reddish cave-earth having a maximum thickness of fourteen inches, and lying on a continuous limestone basis. Beyond a few remains of hyæna nothing of interest occurred in the stalagmite, but the contents of the cave-earth were more numerous and interesting. In July 1887, twenty-four specimens of bones selected from Mr. Else's finds—twenty-one being from the cave-earth in the tunnel and three from the dyke—were forwarded for identification to Mr. E. T. Newton, of the Geological Survey of England, who at the end of a very few days returned them with a list containing not only the names of the species to which they belong, but also those of the bones themselves. Of the twenty-one from the tunnel one is a relic of fox, while all the others are those of the cave-hyæna. The three from the dyke represent the cave-bear, *Rhinoceros tichorhinus*, and a species of deer. Among the tunnel finds there were also three coprolites and a solitary part of a left lower jaw of hyæna divested of its lower border—two facts indicating that the hyæna occasionally visited the tunnel. Here also was found one, and but one, flint-flake tool. It has the white colour so prevalent in the tools found in the cave-earth of Kent's Hole, and was met with under circumstances admitting apparently of no doubt of its having been made and used by a human contemporary of the cave-hyæna in Devonshire.

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2. *The Natural History of Lavas, as illustrated by the Materials ejected from Krakatoa. By* Professor J. W. Judd, *F.R.S., Pres.G.S.*

As a member of the Krakatoa Committee of the Royal Society, the author had been called upon to study the various substances ejected from Krakatoa during the great eruption of 1883. All the lavas which have issued from the central vent of that volcano, since its first formation, belong to the class of the enstatite-andesites. The chemical and mineralogical characters of these rocks have been very fully investigated by Richard, Renard, Sauer, Oebekke, Vom Rath, Reusch, Winkler, Waller, Carvill Lewis, Joly, Bréon, and especially by Verbeek and Retgers; and the further study of these rocks in the light of these researches suggests some conclusions of great geological interest.

A comparison of these enstatite-andesites with others which have been studied with similar care, such as the rocks of Santorin, of the Buffalo Peak, Colorado, and of the Cheviot Hills, reveals some very striking facts. In all of these rocks the minerals present are the same—namely, various species of plagioclase felspar, a ferriferous enstatite, an angite and magnetite with ilmenite; these minerals being embedded in a more or less perfectly glassy base which has nearly the same composition in all of them. Yet some of these rocks on analysis are found to be *basic* in composition, containing only 51 per cent. of silica, while most of them are *intermediate*, and some, the rocks of Krakatoa for example, are distinctly *acid*, having over 70 per cent. of silica. The cause of these differences is found in the fact that the *quantitative* mineralogical constitution is so varied. Some have only 10 per cent. of glass and 90 per cent. of porphyritic crystals, while others have 90 per cent. of glass and only 10 per cent. of crystals.

Although the enstatite-andesites of Krakatoa are all identical in chemical composition and in mineralogical constitution, they nevertheless present us with three very distinct types of rock. Among the older masses we have a stony lava which graduates into a black porphyritic pitchstone. Among the later ejections we find a porphyritic obsidian, which on being distended by the escape of gas forms the well-known Krakatoa-pumice. While the stony lava and pitchstone have a very high fusion-point, the obsidian, which contains a considerable quantity of water, melts at a comparatively low temperature, and in doing so swells up to five or six times its original bulk, forming a true pumice.

The bearing of these facts upon some important geological problems is considered, and reasons are given for doubting whether the porphyritic crystals in a lava have necessarily been developed in the masses in which they are now found.

The important considerations suggested by the late Dr. Guthrie, as the result of his study of the 'cryohydrates' and 'entectic-alloys' are dwelt upon, and it is shown that the silicates, like other salts, have their fusion-points lowered by

admixture with water. This being the case, it is pointed out that a mass of heated rock may become liquefied not only by a rise in temperature, but by the absorption of water into it. Certain facts are described which seem to indicate that the latest ejecta of Krakatoa were formed in this way from the older lavas of the same composition constituting the lower and older part of the volcano.[1]

3. *Report on the Volcanic Phenomena of Vesuvius and its neighbourhood.* See Reports, p. 226.

4. *Seventh Report on the Volcanic Phenomena of Japan.*—See Reports, p. 212.

5. *The Sonora Earthquake of May* 3, 1887.
By T. STERRY HUNT, *LL.D., F.R.S., and* JAMES DOUGLAS, *M.A.*

On the afternoon of May 3, 1887, at 2.12 Pacific time (=120° W. of Greenwich), the first of a series of earthquake movements was felt in the State of Sonora and the adjacent parts of Mexico and the United States, over an area extending from El Paso in Texas on the east, to the river Colorado and the Gulf of California on the west, and from the State of Sinoloa on the south as far north as Albuquerque in New Mexico; the extremes in both directions being over 500 miles. It was the fortune of the writers to be at the time at the great copper-mining camp of Bisbee in Arizona, in a narrow gorge of the Mule Pass Mountains, about 5,300 feet above the sea, and near the border of Sonora. A violent tremor of the earth, including two sharp shocks, and lasting over ninety seconds, was succeeded at frequent intervals by many slighter movements in the next three days, and less frequently at least up to May 29. In this part of Arizona solid house-walls, of *adobe* or unburned brick, were cracked or overturned, while huge rocks in the steep mountain gorges rolled down, causing much damage. Fires, perhaps kindled by these in their course, appeared immediately afterwards in various wooded regions in Sonora and Arizona, giving rise to many false rumours of volcanic eruptions. The movement here seemed from south to north; the Sonora railroad track in one place near the frontier, running east and west, was displaced three inches to the north; while a chimney shaft, without being overturned, was turned violently around upon its base. The small town of Bavispe in the Sierra Madre, in Sonora, was nearly destroyed, many people being killed and wounded. Opoto suffered in a similar way, and Fronteras to a less extent. The district chiefly affected by the earthquake is, however, for the most part a desert, with some cattle ranches and mining stations.

Interesting studies were made by the authors in the valleys, or *mesas,* between the parallel mountain ridges in this region, both in the San Pedro and Sulphur Spring Valleys. The latter, lying to the east of Bisbee, and stretching north and south about one hundred miles, is often eight or ten miles wide, and has its lower portion in Sonora. Though without a visible water-course, water is there generally found at depths of from ten to forty feet in the numerous wells sunk at intervals to supply the needs of large herds of cattle. As described by many observers, the surface of this plain was visibly agitated by the first earthquake shock, so that persons were in some places thrown down by the heaving of the soil, which burst open with discharges of water, while the wells overflowed and were partially filled with sand. In the southern part of this valley, for about seven miles south from the Mexican frontier, the authors found the results of the undulatory movement of the soil apparent in great numbers of cracks and dislocations. For distances of several hundred feet, along some lines with a generally north and south course, vertical downthrows on one side of from one foot to two feet and more were seen, the depressed portion rising either gradually or by a

[1] See *Krakatoa Report of Royal Soc. Com.* and *Geol. Mag.* 1888.

vertical step to the original level. Branching, and in some cases intersecting, cracks were observed. These depressions were evidently connected with outbursts of sand and water, which, along cracks—marked by depressions on both sides—sometimes covered areas of many hundred square feet with layers a foot or more in depth, marked here and there by craters two feet or more in diameter, through which water had risen during the outburst of these mud volcanoes. The authors examined many of these phenomena in northern Sonora, and took photographs, which were exhibited. They note that while the earthquake movements in the adjacent hills of Palæozoic strata had left no marks, the dislocations over many square miles in the valley would have sufficed to throw down buildings and to cause great loss of life in an inhabited region. There are believed to be no evidences of previous earthquake disturbances in this region since its discovery by the Spaniards centuries ago.

From the published reports of commissioners named by the State of Sonora it appears that the regions chiefly injured by the earthquake are in two nearly parallel north and south valleys in the district of Moctezuma, along the river Bavispe, a tributary of the Yaqui. The town of Bavispe itself, of 1,500 souls, lies about seventy miles south of the American frontier and 110 miles south-east of Bisbee, Arizona; its elevation being 3,070 feet above the sea. Here forty-two persons were killed and twenty-five wounded. Bacerao, twenty miles farther south, also suffered much damage, and the estimate for property destroyed in this valley was 218,199 dollars. Opoto, Guasalas, Granados, Bacudebachio, and Nacovi lie in a lower valley about thirty miles west of the last, the elevation of Guasalas being only 1,720 feet above the sea. The loss of life was here confined to Opoto, where nine were killed and six wounded. The injury done to property in this valley was estimated at 78,115 dollars. In both regions are noticed the opening in the arable lands, of numerous fissures, generally north or north-east in direction, from many of which water flowed abundantly. The river, thus supplied in a time of excessive drought, swelled to the volume usual in the rainy season of summer; a condition which lasted up to the time of the report of Señor Liborio Vasquez, dated at Bavispe, May 29, 1887. The fields had become green and the air moist with prevailing fogs. A report concerning the region of Opoto mentions not less than seven volcanoes in the vicinity, which were seen burning for two days, but without any flow of lava; while that for the Bavispe region declares that no volcano had there been discovered. The authors incline to the belief that, as was the case in the San José mountains, and others examined by them along the borders of Arizona, the appearances of volcanoes near Opoto were due to forest fires.

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6. *The History and Cause of the Subsidences at Northwich and its Neighbourhood, in the Salt District of Cheshire.* *By* THOMAS WARD.

The frequent occurrence of subsidences in the neighbourhood of Northwich makes it desirable to learn their history and cause.

Northwich overlies extensive beds of salt. These occupy about three square miles. The first or 'top' rock-salt lies at a depth of about fifty yards from the surface, and is covered by Keuper marls, and these by the drift sands and marls. Between the two beds of salt there are 30 feet of indurated Keuper marl. The second, or 'bottom' rock-salt, is over 30 yards in thickness. These beds of salt occupy the lowest portion of an old Triassic salt lake.

The first bed of rock-salt was discovered in 1670, the second in 1781. From about 1730, at which date the river Weaver and the Witton brook were rendered navigable, until after 1781 all the rock-salt mines were in the 'top' bed, and the whole of these, with one exception, have been destroyed, and in almost every case by water, leaving funnel-shaped, nearly circular, holes. These are now filled with water and are known as 'rock pit' holes. The rock-salt mines are now in the lower bed and very rarely fall in. When worked to the boundary, water and brine, either or both, break in or are let in, and the mines are utilised as huge reservoirs.

The falling in of a rock-salt mine is now a very rare occurrence, and subsidences

of this kind do not give rise to the reports which are met with in the newspapers. The first reported destruction of a mine was in 1750, and from that date to the end of the eighteenth century every two or three years a mine collapsed. In the present century, at considerable intervals of time, collapses of mines have occurred, but these with scarcely an exception were old abandoned 'top' mines.

The subsidences which are so destructive in the town of Northwich and the neighbourhood are entirely caused by the pumping of brine for the manufacture of white salt. It was only about 1770 or shortly afterwards that the first sinking was noticed; since that date subsidence has gone on very rapidly, and much destruction of property has resulted. Large lakes or 'flashes,' one of more than 100 acres in area, and of all depths up to 45 feet, have been and are being formed. Prior to 1770 not more than 30,000 tons of salt were sent down the Weaver navigation; by the end of the century it reached 100,000 tons, and in 1880 had increased to 1,087,000 tons. The whole of this salt was taken off the surface of the first bed of rock-salt by the solvent action of water. In fact, water is the instrument used to mine and carry off the salt to the pumping centre. The brine pumps set up a circulation of the salt water or brine lying on the rock-salt, which flows to the pumping centres. The brine thus removed is replaced by fresh water, which on its passage to the pump saturates itself, taking up sufficient salt to make a solution containing about 26 per cent. of salt. This continual removal of salt from the surface of the rock-salt lowers it, and the overlying earths either follow the diminishing surface continuously or else after remaining suspended for a time suddenly fall into the cavity from which the water has extracted the salt. The brine currents on their way to the pumping centres form deep valleys or troughs, and the surface of the ground overlying forms a facsimile of these hollows. The property on the sloping sides of the valleys is pulled to pieces and destroyed; the windows and doors all get out of form owing to the unequal sinking of the various portions of the house. When, owing to the different nature of the marls and the abundance of sand overlying them, a sudden sinking takes place, the hole extends to the surface and swallows up anything upon the surface—as a horse in a stable, barrels of beer in a cellar, or water-butts and other utensils in a yard. The damage done to property is enormous, but thus far no human life has been lost. The most serious part of the matter is that the brine-pumper takes not only his own salt in solution, but that of all his neighbours over whose salt-beds the water flows, and neither asks their consent nor pays them for the salt thus obtained. Worse even than this, the owner of the property overlying the brine 'runs' suffers most serious damage to buildings, &c., but can obtain no compensation because amongst the number of brine-pumpers he cannot prove who is doing the particular mischief complained of. This peculiar phenomenon of subsidence in the salt districts is worthy of more consideration than it has hitherto received from scientific men.

7. *Places of Geological Interest on the Banks of the Saskatchewan.* *By* Professor J. Hoyes Panton, *M.A.*, *F.G.S.*

The writer, in this paper, after referring to some of the marked geological features which characterise the three great prairie steppes of the north-west, proceeds to describe two localities more particularly, viz. the vicinity of Medicine Hat, situated on the banks of the Saskatchewan 660 miles west of Winnipeg, and a locality near Irvine Station, 20 miles east of Medicine Hat.

From Medicine Hat much coal has been obtained and sent to Winnipeg, and several interesting fossils have been found, consisting chiefly of shells allied to the genus *Ostrea* and fragments of petrified wood. The deposits are identified as belonging to the Belly River series, an American division of the Cretaceous system.

The coal is lignitic in character, showing considerable water and ash, with a tendency to disintegrate when exposed to the air. Contrasted with coal obtained nearer the mountains, it is much softer.

Two seams occur, separated by about 40 feet of clay, shale, &c., with a bed of *Ostrea* and a thin coal. The upper seam is 4 feet 8 inches thick, the lower seam

(that then being worked) is 5 feet 3 inches. Three feet below this is a thinner seam two feet thick.

At the Irvine Ravine the Pierre shales rest upon the Belly River series. At the bottom of the former is a coal seam, but it is not regular enough to work. These deposits are interesting on account of the reptilian remains which seem common amongst them.

Those found by the writer have been identified as belonging to the genus *Lælaps*, allied to the *Megalosaurus*; some other remains of a peculiar character are recognised as portions of the carapace of a land turtle of the genus *Trionyx*.

The deposits are not very uniform in arrangement; the beds consist of alternations of sandstone and clay; some of the latter is greenish in tint and contains selenite.

The following table was given by the writer for comparing the Cretaceous deposits of the north-west, referred to in the paper, with those of the same system in some parts of the United States and Western Europe :—

Western Europe	Missouri, U.S.	North-west of Canada
Eocene, or latest Cretaceous.	Fort Union.	Laramie.
Maestricht.	Fox Hill.	Fox Hill.
White Chalk.	Pierre.	Pierre.
Chalk Marl.	Niobrara.	Belly River.
Upper Greensand.	Benton.	Benton.
Gault.	Dakota.	Dakota.

In the bed of ironstone nodules, a little higher than the river level, excellent fossils of plants allied to the genus *Brasenia* were found.

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8. *The Disaster at Zug on July* 5, 1887. *By the* Rev. E. Hill, *M.A.*

On July 5, 1887, at the town of Zug, in Switzerland, a portion of the shore gave way and sank into the lake. About three hours later another much larger adjacent area also suddenly subsided, so that in all an area considerably over two acres, with half of one of the principal streets, was submerged to a depth of about 20 feet. It can be seen that the subsoil consists of coarse gravel and sand, followed after a few feet by soft wet sand and fine mud. According to Professor Heim, this fine mud or sludge reaches to a depth of nearly 200 feet, and the disaster is shown to be due to a flowing out into the lake of this mobile sludge from under the superincumbent weight of buildings and firmer ground. The buildings collapsed as they sank. The catastrophe must have been long impending; the exact cause which precipitated it is indeterminate, but a low level of the lake and tremors from pile-driving for new quays are suggested as contributories. On the English coast the incessant changes of pressure from tides probably render impossible such instability of equilibrium.

TUESDAY, SEPTEMBER 6.

The following Papers and Reports were read:—

1. *On the Permian Fauna of Bohemia. By* Professor ANTON FRITSCH.

After mentioning the seventy-three species of Labyrinthodants, of which he has given figures in his work ('Fauna der Gaskole'), and of which electrotypes and restored models were exhibited, the author mentioned the discovery of a very peculiar genus *Naosaurus* (Cope). Then he explained some unpublished plates of *Ctenodus, Orthacanthus, Ctenacanthus,* and a new ganoid fish (*Trissolepis*), with three kinds of scales. Then he proved *Acanthodes* to be very near to the Salachians, and drew attention to the gigantic fish (*Amblypterus*), 113 centimetres long, exhibited to the Association.

2. *Report of the Committee for investigating the Carboniferous Flora of Halifax and its neighbourhood.*—See Reports, p. 235.

3. *On the Affinities of the so-called Torpedo* (Cyclobatis, *Egerton*) *from the Cretaceous of Mount Lebanon.*[1] *By* A. SMITH WOODWARD, *F.G.S., F.Z.S.*

In 1844, Sir Philip Egerton read a paper before the Geological Society of London, describing a small Selachian from the chalk of Mount Lebanon, under the name of *Cyclobatis oligodactylus*; six years later, Prof. F. J. Pictet figured a second specimen, showing further anatomical details; and quite recently Mr. James W. Davis has published some notes on the genus, adding a new species, *C. major*. Following Egerton's original determination, the fish seems to have been universally regarded up to the present time as referable to the Torpedinidæ, partly on account of its rounded shape, and partly on account of the supposed absence of dermal defences. The fine series of specimens now in the British Museum, however, appears to demonstrate conclusively that these generally accepted views as to the affinities of *Cyclobatis* have no sure foundation in fact. That the genus is truly referable to the Trygonidæ seems evident from the following considerations: (1) The pectoral fins are uninterruptedly continued to the end of the snout, and were thus probably confluent in front. (2) The pelvic arch is placed far forwards, and the rays of the pelvic fins scarcely extend posteriorly beyond the extremity of the pectorals. (3) There are no traces of median fins. (4) The skin is armed with spinous tubercles. The fact last named has not been noted before; but on the dorsal aspect of the fish there is a longitudinal median row of large spinous tubercles, and the remainder of the body and fins is covered with innumerable prickles. In one small fossil the tail has the appearance of being completely encased in rows of the large tubercles. There is thus no evidence, as yet, of the existence of 'electric rays' of an earlier date than those made known by Volta and Baron de Zigno from the Eocene of Monte Bolca, near Verona, in Northern Italy.

4. *On a Star-fish from the Yorkshire Lias. By* Professor J. F. BLAKE, *M.A., F.G.S.*

The specimen described was an external cast of the under side of a solaster, which was sufficiently well preserved to afford both generic and specific characters. The only known species with which it is comparable is *Luidia Murchisoni*. If this is truly described and is in fact a *Luidia*, then the present specimen, which is certainly a *Solaster*, must belong to a different species. It was found at the base of the cliff at Huntcliff by the Rev. G. Crewdson, of Kendal.

[1] Printed *in extenso* in *Geol. Mag.* dec. iii. vol. iv. pp. 508-510, November 1887.

5. *Thirteenth Report on the Circulation of Underground Waters.*—See Reports, p. 358.

6. *Notice du* Dinotherium, *deux espèces, trouvées en Espagne. By* Professor VILANOVA.

7. *On the Genus* Piloceras, *Salter, as elucidated by examples lately discovered in North America and in Scotland.*[1] *By* ARTHUR H. FOORD, *F.G.S.*

The genus *Piloceras* was first described by Salter in 1859 from imperfect specimens consisting only of what has since been proved to be the siphuncle of a shell closely allied to *Endoceras.*

E. Billings and Sir William Dawson in Canada, and R. P. Whitfield in the United States, have each described and figured species of *Piloceras* in which the septa are preserved. Whitfield has recently ('Bull. Amer. Mus. Nat. Hist. New York,' vol. i. No. 8, December 1886) described a species (*Piloceras explanator*) in which the body-chamber, septa, and fragments of the test are preserved, with the siphuncle in place.

A few years ago Mr. B. N. Peach, of the Geological Survey of Scotland, discovered in the Durness limestone, Sutherlandshire (whence Salter's original specimens were obtained) examples of *Piloceras* in which the septa and siphuncle are seen in conjunction.

These examples may most probably be referred to *Piloceras invaginatum,* Salter.

From a geological point of view *Piloceras* is interesting from its occurrence in rocks forming part of a series which is identical, in order of succession and apparently in fossil contents, in North America and in Scotland.

In an able address to the Royal Physical Society of Edinburgh (1885) Mr. Peach has pointed out that the Silurian strata of Sutherlandshire is represented in Eastern North America by (1) the Potsdam sandstone, bored by *Scolithus,* just like the 'pipe-rock' of Sutherlandshire; (2) the Calciferous Group; (3) part of the Trenton Group.

In consideration of this remarkable similarity between these two widely separated areas, Mr. Peach concludes 'that some old shore-line or shallow sea must have stretched across the North Atlantic or Arctic Ocean, along which the forms migrated from one province to the other, and that some barrier must have cut off this area from that of Wales and Central Europe.'

The genus *Piloceras* may now be thus re-defined :—

Shell more or less broadly conical; slightly curved; somewhat compressed laterally; elliptical in section. Septa rather numerous. Siphuncle formed by the prolongation and conjunction of the necks of the septa; marginal; very large; partaking of the curvature of the shell; provided internally with one or more conical, or funnel-shaped sheaths, which are united at the top with its margin. These sheaths apparently communicated with one another by means of the endosiphon, which perforates the apex of the siphuncle. The endosiphon originated in one of the earlier of the septal chambers, if not in the initial chamber itself.

8. *Report on the Fossil Plants of the Tertiary and Secondary Beds of the United Kingdom.*—See Reports, p. 229.

9. *First Report on the 'Manure' Gravels of Wexford.*—See Reports, p. 209.

[1] Published *in extenso* in the *Geol. Mag.* new ser. dec. iii. vol. iv. December 1887.

10. *The Pliocene Beds of St. Erth, Cornwall.* *By* ROBERT GEORGE BELL, *F.G.S.*

Since the publication of the paper read before the Geological Society of London in February 1886 a good deal of work relating to the geological surroundings and to the special fauna of the deposit has been undertaken. Considerable excavations were made, and much examination given to the sands and clays, with the result that the section given in p. 202, 'Quarterly Journal of Geological Society,' for May 1866, was completely verified.

The clay deposit is not, however, uniformly fossiliferous, nor is it uniform in the distribution of its fossil contents as a rule. Cerithium is found in great numbers at the base of the blue clay, while the larger Nassas and Turritellas are generally distributed in that bed. A great feature of interest is the large number of the smaller species of mollusca, especially of Gasteropods, which embrace more than three-fourths of the total amount.

Of these small shells the genera Rissoa and Odostomia are the most plentiful, in species and numbers; about twenty species of the former (including the Hydrobias) and eighteen of the latter genus are present, some being living inhabitants of the British and Mediterranean seas, while others appear new to science, and will have to be described. The Trochi are nearly all extinct, three only being Crag and living forms. Of Nassa about eight species are present, *Nassa serrata* being by far the most common; it is nearly identical with the general form of *Nassa reticosa*, Sowerby, so plentiful in the coprolite pits of the Boyton district in Suffolk; there are also other well-known Crag species of this family.

The carnivorous Gasteropods are, however, not otherwise plentiful; one should be noticed, a large fragment of *Buccinum undatum*, but no traces of *Fusus antiquus* or *F. gracilis*; all the Pleurotomas are scarce except *P. brachystoma*, and here are two species of Pisania or Lachesis; all these last are southern forms.

Of the bivalves not much can be said; few species were obtained, and these mostly in a fragmentary condition. It is still a difficulty to afford an adequate explanation of this fact, for while the deposit of clay is so well calculated to preserve the shells, as is shown by the perfect state of the univalves, the bivalves (if we except the oysters and some minute species) have universally suffered. Some explanation other than that of the physical character of the deposit must be sought for, and none has yet appeared sufficiently satisfying

The opinion expressed in the earlier reports upon this deposit, as to the southern facies of its fauna, has been amply justified by fresh researches; a large quantity of the fossiliferous clay has been carefully washed and examined, and no trace of northern forms, except *Buccinum undatum*, and the two small species noticed in the paper previously referred to, has been found, while greatly increased evidence confirming what has been already said is present. Had there been any connection with northern seas or colder waters, it would be difficult to understand the entire absence of those forms of Pleurotoma (Bela) so abundant in the Boreal seas of the Crag period and the present age, as well as the equally characteristic bivalves, Astarte and Cyprina.

Some conflict of opinion exists upon the depth of water in which the St. Erth clays were deposited.

In a letter to *Nature*, of August 12, 1886, a very competent authority on Pliocene phenomena, Mr. Clement Reid, F.G.S., gave it as at least forty or fifty fathoms, founding his view on the evident fact of its deposition in still water, which he maintains could not be found in a district exposed to Atlantic swells at less depth. To this the writer must take serious exception. Undoubtedly the clays exhibit an entire absence of such a disturbing cause as the influence of great wave action, but it remains to be proved that such a great depression as Mr. Reid describes did occur at the western end of Cornwall, and as far as I have been able to observe there is little indication of such a fact. Some depression, of course, must have happened, sufficient to submerge the low-lying land near St. Erth, causing a strait or gulf, dividing the Land's End from the main eastern portion of the county.

In this shallow strait the clays and sands were deposited, and just such an assemblage of mollusca is found as will bear out this view. Scarcely any of the shells which are of living species are known to inhabit such deep water as Mr. Reid indicates, while the majority show the presence of a laminarian zone, extending to not more than fifteen fathoms. This bathymetrical range is the chosen habitat of the Rissoæ, who are all vegetable feeders, and of the Nassas, which are predatory and always plentiful just below low-water mark; and what appears still more conclusive is the number of Hydrobias, which have a close connection with Littorina, and indicate shallow depth and close proximity to shore.

It is hoped that a more detailed examination of the molluscan fauna may soon be completed, and the whole series added to the national collection.

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11. *Report on the Higher Eocene Beds of the Isle of Wight.*—See Reports, p. 414.

WEDNESDAY, SEPTEMBER 7.

The following Papers were read:—

1. *The Triassic Rocks of West Somerset.* *By* W. A. E. Ussher, *F.G.S.*

This paper forms a necessary supplement to a series of papers on the Triassic rocks of Devon, Somerset, &c., communicated to the Geological Society by the author in the years 1876, 1878, and 1879. In the first two communications reference was made to the probable existence of Infra-keuper beds in the area between Williton and Porlock, inferred from a brief visit. This opinion was given with some reservation; it would entail the existence of a considerable fault which, not then being able to study the Devonian rocks of the area, the author was unable to verify.

The present contribution is the result of subsequent investigations, made in the years 1878 and 1879. The constitution, extent, and general relations of the Lower, Middle, and Upper Triassic rocks of the area are briefly described seriatim, with the following general results:—

The Lower Trias consists of breccia and breccio-conglomerate upon sands and brecciated sand and loam; it occupies the east of the valley, extending from Lydeard St. Lawrence northward to Vellow Wood Farm, south of Sampford Brett, where it finally disappears, being faulted against Keuper basement beds and conformably overlapped by Middle Trias marls upon the margin of the older rocks.

The Middle Trias, consisting of marls with sandstones in places at their base, occupies the centre of the valley, being faulted against the successive divisions of the Keuper on the east, and terminating northward in the angle made by convergent faults at Bicknoller. The Middle Trias marls rest on the older rocks near Vellow Wood Farm, and finally disappear near Orchard Wyndham, south of Williton, under Keuper breccias.

The Keuper beds consist of marls, sandstones, and a locally varying series of conglomerates, gravels, and breccia in descending sequence. The sandstones are very calcareous south of Crowcombe; they form marginal deposits in places near Dunster. In the Porlock valley they constitute an insignificant horizon, and at Sampford Brett have local intercalations of marl at their base.

The coarser beds of the Keuper develop at the expense of the sandstones in the area west of Williton. In the form of incoherent gravels they constitute outliers on the Middle Trias marls. The massive conglomerates occur locally to the north of Crowcombe Heathfield station. Near Beggearn Huish, and in the Porlock valley, the Keuper basement beds resemble varieties of Lower Trias breccias in the Tiverton area, having been deposited under analogous conditions.

It is very probable that the Keuper basement beds of the Porlock valley may be marginal deposits formed during a progressive subsidence, and therefore may belong to a higher horizon than the Lower Keuper beds south of Williton.

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2. *The Devonian Rocks of West Somerset on the Borders of the Trias. By* W. A. E. Ussher, *F.G.S.*

The composition of the Quantocks is first briefly described, and the faulted relations of the middle Devonian grits, slates, and limestones of which they consist alluded to. From the constitution of the Palæozoic districts on the east and west of the Triassic rocks of Crowcombe and Stogumber the author considered the beds eroded in the intervening valley would amply account for the variability of the Triassic strata derived from them. From Withycombe to Porlock the faulted relations of the middle and lower Devonian grits are then briefly described. The author considered that the elevation of the Quantocks, the Brendon, and the Dunkery ranges was pre-Triassic, accompanied by faulting on an extensive scale; that many lesser faults were produced in post-Triassic times, and that further movements took place along the old lines of fracture. He did not believe that the Devonian highlands were ever covered by secondary sediments, but was of opinion that the Triassic rocks never extended far beyond their present boundaries, except in old valleys from which they had subsequently been almost entirely removed by denuding agencies.

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3. *The Matrix of the Diamond. By* Professor H. Carvill Lewis.

A microscopical study of the remarkable porphyritic peridotite which contains the diamonds in South Africa demonstrates several interesting and peculiar features.

The *olivine*, forming much the most abundant constituent, is in porphyritic crystals, sometimes well bounded by crystal faces, at other times rounded and with corrosive cavities, such as occur in it in basaltic rocks. It rarely encloses rounded grains of glassy bronzite, as has been observed in meteorites. The olivine alters either into serpentine in the ordinary way, or into an aggregate of acicular tremolite crystals, the so-called '*pilit*,' or becomes surrounded by a zone of indigo blue bastite—a new variety of that substance. The olivine is distinguished by an unusually good cleavage in two directions.

Bronzite, *Chrome diallage*, and *Smaragdite* occur in fine green plates, closely resembling one another. The bronzite is often surrounded by a remarkable zone, with a centric, pegmatitic, or chondritic structure, such as occurs in certain meteorites. This zone is mainly composed of wormlike olivine grains, but a mineral having the optical characters of cyanite also occurs in this zone.

Biotite, a characteristic constituent, occurs in conspicuous plates, often twinned, generally rounded, and distinguished by its weak pleochroism, a character peculiar to the biotite of ultra-basic eruptive rocks. It alters by decomposition into the so-called *Vaalite*.

Perovskite occurs in very numerous but small crystals, which optically appear to be compound rhombic twins.

Pyrope is abundant in rounded red grains. Titanic iron, chromic iron, and some fifteen other minerals were also found. Rutile is formed as a secondary mineral through the alteration of olivine into serpentine, being a genesis of rutile not heretofore observed.

The *chemical composition* shows this to be one of the most basic rocks known, and is a composition which by calculation would belong to a rock composed of equal parts of olivine and serpentine, impregnated by calcite.

The *structure* is at the same time porphyritic and brecciated, being one characteristic of a volcanic rock which after becoming hard had been subjected to mechanical movements. It is a volcanic breccia, but not an ash or tuff, the peculiar structure being apparently due to successive paroxysmal eruptions. A similar structure is known in *meteorites*, with which bodies this rock has several analogies. A large amount of the adjoining bituminous shale is enclosed, and has been more

or less baked and altered. The occurrence of minute tourmalines is evidence of fumarole action.

The microscopical examination supports the geological data in testifying to the igneous and eruptive character of the peridotite, which lies in the neck or vent of an old volcano.

While belonging to the family of peridotites, this rock is quite distinct in structure and composition from any member of that group heretofore named. It is more basic than the picrite porphyrites, and is not holocrystalline like dunite or saxonite. It is clearly a new rock-type, worthy of a distinctive name. The name *Kimberlite*, from the famous locality where it was first observed, is therefore proposed.

Kimberlite probably occurs in several places in Europe, certain garnetiferous serpentines belonging here. It is already known at two places in the United States: at Elliott County, Kentucky, and at Syracuse, New York; at both of which places it is eruptive and post-carboniferous, similar in structure and composition to the Kimberley rock.

At the diamond localities in other parts of the world diamonds are found either in diluvial gravels or in conglomerates of secondary origin, and the original matrix is difficult to discover. Thus, in India and Brazil the diamonds lie in a conglomerate with other pebbles, and their matrix has not been discovered. Recent observations in Brazil have proved that it is a mistake to suppose that diamonds occur in itacolumite, specimens supposed to show this association being artificially manufactured. But at other diamond localities, where the geology of the region is better known than in India or Brazil, the matrix of the diamond may be inferred with some degree of certainty. Thus, in Borneo, diamonds and platinum occur only in those rivers which drain a serpentine district, and on Tanah Laut they also lie in serpentine. In New South Wales, near each locality where diamonds occur, serpentine also occurs, and is sometimes in contact with carboniferous shales. Platinum, also derived from eruptive serpentine, occurs here with the diamonds. In the Urals, diamonds have been reported from four widely separated localities, and at each of these, as shown on Murchison's map, serpentine occurs. At one of the localities the serpentine has been shown to be an altered peridotite. A diamond has been found in Bohemia in a sand containing pyropes, and these pyropes are now known to have been derived from a serpentine altered from a peridotite. In North Carolina a number of diamonds and some platinum have been found in river sands, and that State is distinguished from all others in eastern America by its great beds of peridotite and its abundant serpentine. Finally, in northern California, where diamonds occur plentifully and are associated with platinum, there are great outbursts of post-carboniferous eruptive serpentine, the serpentine being more abundant than elsewhere in North America. At all the localities mentioned chromic and titanic iron ore occur in the diamond-bearing sand, and both of these minerals are characteristic constituents of serpentine.

All the facts thus far collected indicate *serpentine*, in the form of a decomposed eruptive peridotite, as the original matrix of the diamond.

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4. *Observations on the Rounding of Pebbles by Alpine Rivers, with a Note on their Bearing upon the Origin of the Bunter Conglomerate.*[1] *By* Professor T. G. BONNEY, *D.Sc., LL.D., F.R.S., F.G.S.*

The author describes the result of his observations of the rounding of pebbles in various torrents and rivers in the Tyrol and Dauphiné, and of the gravels of the Piedmontese and Lombard plains. These lead to the following conclusions, among others: (*a*) that pebbles are rounded with comparative rapidity when the descent of the stream is rapid, and they are dashed down rocky slopes by a roaring torrent, capable of sweeping along blocks of much greater volume; (*b*) that pebbles are rounded with comparative slowness when the descent is gentle and the average pace of the river is about adequate to push them along its bed. The rocks

[1] *Geol. Mag.*

observed were in some cases limestone and not very hard grits; in others various crystalline rocks, such as granite, gneiss, or mica-schist. Hence, as the majority of the pebbles in the Bunter are of harder material, and are generally better rounded than those which the author observed, he concludes that it is impossible to suppose them mainly derived from any tract of land which, in Triassic times, can have existed in either Central or Eastern England, for they must have been formed by rivers no less important, with courses either longer or steeper than those of Central Europe. Thus these observations are very favourable to the view which ascribes to them a Scotch origin, where alone rocks exactly like them are known to occur.

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5. *On the Present State of the Channel Tunnel, and on the Boring at Shakespeare Cliff, near Dover. By* Professor W. BOYD DAWKINS, *F.R.S.*

The present condition of the experimental heading of the Channel Tunnel Company is now, after the lapse of five years, a most important fact bearing on the feasibility of a Channel tunnel at all.

A careful examination of the heading on July 23, 1887, proves that the conclusions which were arrived at when the enterprise was begun, as to the ease with which a tunnel can be constructed, the security from inroads of the sea resulting from its being made in the grey chalk, and the small cost at which it can be made and maintained, have been fully justified by the present condition of the works.

The heading, 7 feet in diameter and $1\frac{1}{4}$ miles in length, and for upwards of a mile actually beneath the sea-bottom, is practically free from water. In driving it the total quantity of water met with amounted only to $3\frac{1}{3}$ gallons per minute. This small amount has now diminished to the odd one-third of a gallon per minute, almost all of which is derived from a spring in the broken materials in the shaft, occurring 30 feet from the surface. The fact that the heading not only remains dry after standing for five years, but is drier now than when it was driven, shows that no danger is to be anticipated from the inroad of the sea into the tunnel beneath the bottom of the Straits of Dover, or from the influx of water from the land.

Nor has the heading shown any signs of movement, although it is unlined, and has been exposed to atmospheric agencies for five years. The chalk has not swelled or changed its form; it retains the tool-marks of the boring machine, as clearly and sharply defined as on the day when they were made. It stands perfectly, and has become harder, as it has lost the water in its capillary pores.

The dip of the strata lends itself with singular facility to the gradients which are best adapted to the working of the traffic, and the defence of the tunnel by flooding.

After taking all these facts into consideration, it is clear that the original estimate for the English half of the tunnel of 1,527,000*l.* is amply confirmed by the experience obtained. The dryness and stability of the heading prove further that the cost of the maintenance of the tunnel will be exceptionally low.

The geological evidence is conclusive that the valuable coalfields of South Wales and of Somerset are connected with the equally valuable coalfields of North France and Belgium, some 1,200 square miles in extent, by a series of isolated fields or basins concealed by the newer rocks. The coal-measures in Northern France pass westwards in the direction of Calais, and plunge under the newer rocks near Condé, from which point to Thérouanne they extend and are worked under two departments, their discovery being due to borings carried out at the expense of the French Government. The last-named place, some 30 miles to the east of Calais, is the farthest point to the west where they have been worked. At Calais, however, they have been proved at a depth of 1,092 feet below Ordnance datum. From this point westward they have not been struck until we reach Somersetshire.

The borings for water, however, made in the London area show that the water-worn primary rocks which come to the surface in the West of England and in North France and Belgium occur under London at a distance of not more than 1,200 feet from the surface, and that these are highly inclined as in those regions.

These rocks are of Silurian and Devonian ages, and older than the Carboniferous. Their high inclination, however, implies that the strata are there thrown into folds, and that in some neighbouring area the Carboniferous rocks must come in. In my opinion they will be searched for and found.

The boring which is now being carried on under my direction and that of Mr. Francis Brady is an attempt to solve this most important problem, and the place selected is close to Shakespeare Cliff, near Dover. We began in the grey chalk, and we have got down 543 feet to the top of the weald clay. At Calais there are no wealden strata, and the Carboniferous rocks occur at the very point in the geological section where we are now. The older strata will probably be struck at a depth of less than 1,000 feet, and probably at a very much less depth. If the coal-measures are proved, a discovery of vast importance will be made. If, on the other hand, rocks older than the Carboniferous are struck, they will offer a basis for future borings which will result in the discovery of these hidden coalfields, and cause an economic revolution in South-eastern England as great as that which has been brought about by the working of coal under the chalk in France and Belgium.

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6. *On the Extension of the Scandinavian Ice to Eastern England in the Glacial Period. By* Professor OTTO TORELL.

1. The principal mass of solid ice that during the Glacial period extended from Scandinavia as a centre advanced, according to the slope of land, to the south and south-east, covering a great part of Russia in Europe, Northern Germany, and the Netherlands. As ice moves according to the same laws as water, it is evident that the long and deep channel of the Baltic would be a highway for the movement of a great part of it, and that the resistance of land to the east would tend to cause the ice to deviate towards the south-west.

2. This can be proved by the large number of Silurian boulders from the Baltic provinces, such as porphyries from Dalecarlia, Småland, and the Åland Islands, which are met with in Holstein and the Netherlands. A line drawn along the axis of the Baltic will cross Holstein and Groningen, in Holland, and reach the shore of Norfolk. That this *Baltic-Dutch ice-stream* moved over the bottom of the southern part of the North Sea, and extended over the eastern part of Norfolk, may be proved by the occurrence of erratics, undoubtedly of Swedish origin, in the Cromer till, between Happisbury and Cromer. Thus, I have found there the well-known red porphyry from Dalecarlia, which is so common in the Glacial deposits of Germany and Halleflintas from Eastern Småland, in South Sweden.

The succession of beds of till, boulder clay, and stratified sands and gravel on the coast of Cromer, which I have visited several times within a period of more than twenty years, are true Glacial deposits, identical with the Glacial beds in South Sweden and North Germany. They have been produced by the combined action of solid ice and Glacial rivers from it. They were described with great accuracy by Mr. Clement Reid, of the Geological Survey.

1. At the bottom are the first and second tills, true ground moraines with a bed of sand between them.

2. Above these lie stratified beds of sand and loam, probably equivalent to the Middle Glacial sands in South Sweden and North Germany.

3. Then there is an upper boulder clay, which may be the moraine of the retreating ice-stream; and

4. On the top other beds of sand and gravel, which I believe to have been deposited by the rivers derived from the retreating ice.

All these beds belong to the *contorted drift* as a whole.

Not until the ice reached the shore would rivers arise from it, but when it did so these rivers would form their own beds of sand and gravel. It is very likely that these beds may be in part represented by the Bure valley gravels of Mr. Searles Wood, which in like manner were afterwards covered by the ground moraines of the advancing ice, just as the oldest 'Diluvial sand' of the German, and the Alluvion ancien of Swiss geologists, are met with below the oldest ground moraines.

Another large ice-stream, which advanced from the Alps of South-western Norway and the adjoining regions of Sweden to the eastern shores of England, covered a great part of South-eastern Yorkshire, Lincolnshire, and the adjoining counties. As it filled up the Skagerack and crossed the North Sea, where it must have met the Baltic-Dutch ice-stream, I have called it the *Skagerack-North Sea ice-stream.*

The northern part of Jutland is covered by the boulders which it brought from Norway, especially the Rhomb porphyry from Christiania. Many years ago I found this porphyry at Grimsby, and Mr. Helland, I believe, has met with it and the syenite of Fredriksveem in Holderness. Just as the axis of the Baltic may be prolonged to Norfolk, so a line drawn through the middle of the Skagerack will meet the coast of Yorkshire. At Bridlington and elsewhere in Holderness the beautiful ground moraines of this ice-stream—the casement or chalky clay of Mr. Searles Wood, jun.—are open for study. As this great mass of ice grew in size, whilst, owing to causes which I am just beginning to understand, the Baltic-Dutch ice-stream diminished, most extraordinary phenomena resulted. The strata of the chalk and other formations below the ice were partly broken up, moved along from north-east to south-west, and even destroyed by it. Of these phenomena Mr. Skertchly has given a graphic description.[1]

The great chalky boulder clay of Mr. Wood is probably a moraine of the same ice-stream.

Mr. Wood describes extensive beds of sands underlying this clay to the south as 'the Middle Glacial sands.' These, I suspect, are equivalent to the 'Diluvial sand' in Germany, and Alluvion ancien in the Alps, and were deposited by the Glacial rivers from the ice-stream.

That the great chalky boulder clay is a real ground moraine there seems to be no doubt. According to Mr. Wood the great chalky boulder clay is later than the Cromer beds. It seems really to be the case that the Baltic-Dutch ice-stream, which deposited the Cromer series of beds, retreated before the greatest advancement of the Skagerack-North Sea ice-stream. If, then, this ice-stream encountered the Glacial beds at Cromer, the result would be such phenomena as the well-known contortion of the drift there. The strata would be raised up and contorted in every direction. As the bottom of the sea to the north-east of Cromer consists of chalk, the ice could plough up and carry large masses with it and press them into the drift as it contorted it. These boulders generally consist of reconstructed chalk broken up into innumerable fragments cemented together again. One of these boulders, that of West Runton (Woman Hithe), is more than 600 feet long and 80 feet high, and has been pushed through the whole of the contorted drift from top to bottom. Mr. Reid has expressed his opinion that only solid ice could cause the contortions, but he does not consider how it may be explained that the same strata which are formed by ice should since have been disturbed by the same agency. On the island of Hven, in Oresund, similar phenomena on a smaller scale may be seen. There older Glacial beds are overlain by sands and clays, all formed by a stream of ice from the north-east. These were afterwards encroached upon and partly destroyed by a later ice-stream from the Baltic, and phenomena similar to those of the contorted drift at Cromer were produced.

If the explanation which I have given is correct we have at Cromer evidence that—

1. The *Baltic-Dutch ice-stream* deposited till on the Norfolk coast.
2. This ice-sheet retreated while the *Skagerack-North Sea stream* advanced southwards, so as to crush into these deposits, contorting them and forcing into them masses of chalk torn from the sea-bed outside.

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7. *On the Terminal Moraine near Manchester.* *By* Professor H. Carvill Lewis.

A line of drift hills passing in a south-easterly direction close to the city of Manchester is here described in detail, and held to be a portion of the terminal

[1] In Professor Geikie's *The Great Ice Age.*

moraine of the Irish Sea glacier. Erratics from the Lake district and Scotland, and flints and shell fragments from the bed of the Irish Sea, distinguish this moraine from others farther north. No striæ and no shell fragments have been discovered to the north-east of this line of drift hills, while to the south and west of it both striated rock surfaces and shell-bearing drift are abundant. Although frequently levelled down by natural and artificial agencies, in many places these drift hills retain the typical features of a moraine.

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8. *On a simple method of projecting upon the screen Microscopic Rock Sections, both by ordinary and by polarised light. By* E. P. Quinn.

Knowing the difficulty experienced in pointing out to students any particular crystal in a rock section when viewed with the microscope direct, I attempted to project the images on the screen, and by the aid of comparatively simple apparatus met with very gratifying success, both with ordinary and with polarised light.

The tube of the microscope was screwed out and replaced with a cork, through which a hole had been cut to carry the ordinary one-inch micro-objective, and behind it the analyser of the microscope. The polariscope and rock section occupied their usual position as when used with the microscope in the ordinary way. The microscope stand being inclined into the horizontal position was placed in front of the object lens of the lime-light lantern. The object lens of a lantern usually consists of a combination of two lenses. If so the back lens is taken out and the front lens only used, acting as an extra condenser, concentrating the light upon the rock section and causing it to pass through the polariser and the analyser.

A little adjustment of the light was required to get it well through both polariser and analyser, but this with a little care was soon done, and a bright picture, several feet in diameter, was projected upon the screen, showing the crystals well defined and exhibiting very strikingly the changes of colour, &c., characteristic of the crystals when viewed by polarised light, and in such a manner as to be well seen by a number of people at once, and also allowing the lecturer to readily point out any particular crystal or crystals to which he desires to draw the attention of his audience. As the optical axis of the lantern and microscope did not coincide, the lantern was placed on a board provided with four levelling screws, with which the necessary adjustments were readily made.

Much better effects may be got if the 'Prazmowski' form of prisms made by Zeiss are used instead of the usual Nicolls prisms, on account of their greater aperture and shorter length, and the most brilliant results with the one-inch objective of fifty angular apertures by Wray of London.

SECTION D.—BIOLOGY.

PRESIDENT OF THE SECTION.—ALFRED NEWTON, M.A., F.R.S., F.L.S., V.P.Z.S., ETC., Professor of Zoology and Comparative Anatomy in the University of Cambridge.

THURSDAY, SEPTEMBER 1.

The PRESIDENT delivered the following Address:—

IN opening the business of this Section I cannot but call to mind the last occasion when the British Association met in the city of Manchester, just six-and-twenty years ago; and, while my memory brings back to me many pleasing recollections of that gathering, I cannot help dwelling upon the extraordinary difference between the state of things that then existed and that which we have before us to-day. The moral of the contrast I shall not seek to enforce. Those, if any there still be, who despair of the future of our Association may reflect upon it at their leisure; while those who believe, as I do, that our Association has no justifiable cause for thinking that its work is accomplished, that it had better settle its worldly affairs, and compose its robes around it in a becoming fashion, before lying down to die, will at once appreciate the difference.

Yet there is one difference between our proceedings to-day and those of more than a quarter of a century since which I, personally, do not appreciate. In that remote and golden age it had not become obligatory on the President of this Section to prepare beforehand an Address to be delivered to a critical, even though kindly, audience. A few words of friendly greeting to old faces, and a hearty welcome to those that were new, with a general statement of the objects of our coming together, comprised all that was expected from the occupant of the chair. Such was the case when my predecessor, who was, I may observe, my excellent friend and colleague, Professor Babington, opened the proceedings of this Section—then called the Section of Zoology and Botany—at Manchester in 1861; and I am sure I have reason to envy his happy lot, for, on refreshing my memory by turning to the Report of that meeting, I find that his introductory 'Remarks' occupy a space of less than eight lines of print. In this respect, but in this only, I must confess myself *laudator temporis acti*, and it having now been for so many years the practice of your President to deliver an Address on occasions like the present, I feel that I should be filling my position under false pretences did I not conform to established usage, though I am well aware that what I have to say will, for many reasons, hardly bear comparison with what has been said by many of my distinguished predecessors.

But to continue the contrast of what took place in this Section at our last meeting in Manchester with what may be expected to happen now, I would remark that the year 1861 was one which, when the history of biology comes to be written, will be found to deserve particular recognition. This is not merely because of the all-important discovery of *Archæopteryx*, for that had not been made known when the Association met, and did not affect our proceedings here. When we met, it was a time, so to speak, of 'slack water'; but slack water is commonly the effect of two contrary streams, and perhaps I ought to state how this came about. All present should be aware that it was before the Linnean Society on the

First of July, 1858, that the stupendous announcement was made of a theory which for the first time brought to the notice of biologists a reasonable explanation of the mode by which what had hitherto passed under the name of the Transmutation of Species could be effected. It is notorious that this announcement attracted but little attention at first, and, though it were easy to account for this fact, I see no need to occupy your time by so doing. I would, however, beg your attention to another fact which is by no means notorious. So far as I am aware, the first zoologist publicly to accept and embrace the theory propounded on that memorable evening on behalf of Mr. Darwin and Mr. Wallace was my old friend Canon Tristram, and moreover he did this ere little more than a twelvemonth had expired.[1] To me it will always be a matter of rejoicing that the adoption of this theory was so early accepted, and additional evidence in its favour adduced, by one who has devoted so much time and energy to the particular branch of zoology which has long recommended itself to me; for thereby I hope that the study of ornithology may be said to have been lifted above its fellows. This, however, is a digression, for introducing which I trust I may be pardoned. And now to return to my main business. Late in the autumn of 1859, as you know, Mr. Darwin's essay on the 'Origin of Species' appeared—a mere abstract, as it still remains, of an enormous mass of materials industriously accumulated by him through many long years—a mass out of which, as he himself has modestly said, a competent man might have written 'a splendid book'—but a mass with which he, chiefly through ill-health, had been unable to deal properly. Yet I am not sure that we have any reason to lament the result. The handy size of that celebrated little volume gave it a power of penetration and circulation that would not have been possessed by a work of greater bulk, while the studied absence of technicalities and of reference to scientific authorities in the form of foot-notes (which last, I need scarcely point out, would have largely increased its dimensions) brought its closely-reasoned argument within the comprehension of hundreds whom it would have at once repelled had it been made up of learned phraseology.

Much of what followed on the publication of this work will be in the recollection of many of my audience, while the rest must have heard of it from their seniors. The ever-memorable meeting of this Association at Oxford in the summer of 1860 saw the first open conflict between the professors of the new faith and the adherents of the old one. Far be it from me to blame those among the latter who honestly stuck to the creed in which they had educated themselves; but my admiration is for the few dauntless men who, without flinching from the unpopularity of their cause, flung themselves in the way of obloquy, and impetuously assaulted the ancient citadel in which the sanctity of 'Species' was enshrined and worshipped as a palladium. However strongly I myself sympathised with them, I cannot fairly state that the conflict on this occasion was otherwise than a drawn battle; and thus matters stood when in the following year the Association met in this city. That, as I have already said, was a time of 'slack water.' But though the ancient beliefs were not much troubled, it was for the last time that they could be said to prevail; and thus I look upon our meeting in Manchester in 1861 as a crisis in the history of biology. All the same, the ancient beliefs were not allowed to pass wholly unchallenged; and one thing is especially to be marked—they were challenged by one who was no naturalist at all, by one who was a severe thinker no less than an active worker; one who was generally right in his logic, and never wrong in his instinct; one who, though a politician, was invariably an honest man—I mean the late Professor Fawcett. On this occasion he brought the clearness of his mental vision to bear upon Mr. Darwin's theory, with the result that Mr. Darwin's method of investigation was shown to be strictly in accordance with the rules of deductive philosophy, and to throw light where all was dark before.

Now the reason why I have especially mentioned this essay of Professor Fawcett's is not merely that the approval of the disputed theory by such a man did not a little contribute to the success which was then impending, but because I have for a long while maintained that, as a matter of fact, what is now known as the

[1] *Ibis*, October 1859, pp. 429–433.

Darwinian theory did not, except in one small point, require a naturalist—and much less naturalists of such eminence as Mr. Darwin and Mr. Wallace—to think it out and establish its truth. Pray do not for a moment imagine that I wish to detract from the value of their demonstration of a discovery that is almost unrivalled in its importance when I say that the demonstration might have been perfectly well made by any reflective person who was aided by that small amount of information as to the condition of things around him, which is presumably possessed by everybody of common sense. It might have been perfectly well made by any of the sages of antiquity. It might have been as well made by any reasoning man of modern time, even though he were innocent of the merest rudiments of zoology or botany; and, as is admitted, the discovery was partly and almost unconsciously made by Dr. Wells in 1813, and again by Mr. Patrick Matthew in 1831—neither of whom pretended to any special knowledge of those branches of science. It is equally a fact that anyone who applied the doctrine of Malthus, the political economist' to the animal and vegetable populations of the world, could have seen that what came to be called 'Natural Selection' was the necessary consequence of the principles enunciated by him; and we have Mr. Darwin's acknowledgment that his reading the 'Essay' of Malthus was with him the turning-point which settled his conviction as to the soundness of the crude speculations in which he had been indulging. Moreover, years before Malthus wrote, a great French writer, though no naturalist, had pointed out, in terms that were *mutatis mutandis* repeated as regards plants at a later time by the elder De Candolle, that all animals were perpetually at war; that each, with a few exceptions, was born to devour others; and that the males of the same species carried on an internecine war for the females.[1] The fact of the 'Struggle for Life' being thus recognised all the rest should follow, and really no close acquaintance with natural history was needed to guide an investigator to the end so far reached.

But in order to see the effect of this principle upon organic life the knowledge—the peculiar knowledge—of the naturalist was required. This was the knowledge of those slight variations which are found in all groups of animals and plants—a point on which I need not now dwell, for to my present audience it must be known in thousands of instances. Herein lay the triumph of Mr. Darwin and Mr. Wallace. That triumph, however, was not celebrated at Manchester. The question was of such magnitude as to need another year's incubation, and the crucial struggle came a twelvemonth later, when the Association met at Cambridge. The victory of the new doctrine was then declared in a way that none could doubt. I have no inclination to join in the pursuit of the fugitives.

But in tracing briefly, as I am now doing, the acceptance of the teaching of Mr. Darwin and Mr. Wallace, there is one point on which I should like to dwell for a few moments, because it has, so far as I know, been very much neglected. This is the great service rendered to the new theory by one who was its most determined opponent, by one of whom I wish to speak with the utmost respect, by one who was thoroughly a philosophical naturalist, and yet pushed his philosophy to overstep the verge of—I fear I must say—absurdity. I mean the late Professor Louis Agassiz, whose labours in so many ways deserve far higher praise than it is in my power to bestow. There must be many here present who will recollect the time when the question 'What is a "Species"?' was always coming up to plague the mind of every zoologist and botanist. That question never received a definite answer, and yet every zoologist and botanist of those days felt that an answer ought to be given to it; for without one they knew that they were sailing on an unknown sea, and that theirs was likely to be lost labour. The chief reason why no answer was given lay in the fact that hardly any two zoologists or botanists could agree as to the kind of reply which should be made, for hardly any two of them

[1] Tous les animaux sont perpétuellement en guerre; chaque espèce est née pour en dévorer une autre. Il n'y a pas jusqu'aux moutons et aux colombes qui n'avalent une quantité prodigieuse d'animaux imperceptibles. Les mâles de la même espèce se font la guerre pour les femelles, comme Ménélas et Paris. L'air, la terre et les eaux sont des champs de destruction.—Voltaire, *Questions sur l'Encyclopédie par des Amateurs*, article 'Guerre.'

could agree as to how a 'Species' was constituted. It will be enough for me to say now that Louis Agassiz pinned his faith on every 'Species' being not merely the result of a single direct act of creation, but, when he found that physical barriers interposed (as they often do) between two or more parts of the area which the 'Species' occupied, he did not hesitate to declare that a 'Species' might have been created directly in several places, at sundry times, and even in vast numbers. If the same Species of freshwater Fish, for instance, was found in several rivers which had no intercommunication, it had been, he asserted, separately created in each. Before his time people had been content to talk of each Species having had a single birthplace—its own 'Centre of Creation'—but he maintained that many species must have had *several* Centres of Creation, and creation was in his mind no figurative expression. He meant by it, just as Linnæus before him had meant, a direct act of God; in other words his belief was that there had been going on around us a series of mysterious performances, not one of which had ever been consciously witnessed by a human eye, but each of which had for its object the independent formation of a new living being, animal or plant. That is to say that there had been going on from time indefinite a continuous series of operations which could only be termed miraculous, since there was no known natural law by means of which they could be produced. Though the author of this theory was, in the country of his adoption, regarded as the especial champion of opinions that are commonly termed orthodox, it is not surprising that many minds revolted from such a conclusion as it required—a conclusion which they not unfitly deemed a *reductio ad absurdum.* Yet the position of Professor Agassiz was perfectly logical when once his premisses were admitted; and, more than that, it became obvious to all clear-seeing men that one of these alternatives must be adopted—either Agassiz's logical doctrine of Centres of Creation, or the theory of the Transmutation of Species, which had been so long condemned because no reasonable explanation of its *modus operandi* was known.

I have called these alternative opinions because I believe that no third course had been suggested by any naturalist, and yet it is hard to say which of them was most unpalatable to the world at large. On the one hand people were called upon to believe that Man was in some inexplicable and unaccountable way produced from a Monad. On the other hand they were called upon to believe that the inhabitants, vegetable and animal, whether bestial or human, of nearly every group of islands in the Pacific Ocean were the result of innumerable special acts of Creation entirely performed within the limits of almost each cluster of coral reefs. The natural consequence of this was that most people, and even most biologists, remained in an apathetic if not an unthinking condition on this subject, and went on as their fathers had done, not caring to trouble themselves in this matter. It was only a few—an extremely few—among them who ever gave the question any consideration at all, and these few were not so much the men who had confined their labours to museums, libraries, or laboratories, but they were, with scarcely an exception, men who had studied Nature in the field, and had seen her works under varied aspects in the most distant and diverse climes. They were of the men who had personally compared the geological formations of the Old World and the New, men who had circumnavigated the globe, who had surveyed Antarctic volcanoes or Himalayan snows, who had dredged the depths of Australian oceans or had explored Amazonian forests. Out of the abundance of their observation and reflection these men—to this audience I need not name them—in due time delivered their verdict, and when it was delivered its effect was crushing. The position of the supporters of the doctrine of 'Centres of Creation,' logical as it had seemed, was swept away—not of course without a gallant struggle on the part of its defenders—and the theory of the 'Transmutation of Species,' fanciful and unreasonable as it had been thought, was under a new name established, the very fact of its success being an additional proof of, to use Mr. Herbert Spencer's happy phrase, the 'Survival of the Fittest.'

But perhaps some of you have been thinking or whispering to your neighbours, 'Why should our president be taking up our time by making us listen to all these platitudes, this old story with which we are all familiar?' and if you have

been so doing you will have some excuse, but I trust you will think that I also have some excuse in thus recurring to what may be almost deemed a portion of ancient history when I state that in my belief this year 1887 will in future be remembered as that in which 'The Life and Letters' of our great biologist, Charles Darwin, appeared; and I hope that in a few minutes you will admit that in accordance with the fitness of things it is meet and right that this should be so. There can be little doubt that before the end of this year that work which all naturalists have been expecting with so much anxiety will be published, and published moreover in three languages. It can hardly fail to be accounted by biologists as the chief event of the year. By favour of its author, Mr. Francis Darwin, I have been allowed to see some of his proof-sheets, and I am sanguine that it will not disappoint the expectations of its readers. On one point I venture to speak with some certainty. The noble character of the man will be made manifest to the world in words and deeds that cannot be spoken against, and we may feel assured that in future

> Whatever record leap to light,
> He never shall be shamed.

He is unsparing of his own mistakes or shortcomings; and, while admitting with the utmost generosity the assistance he received from others, the dignified way in which he thought and expressed himself toward the many who attacked him, often unscrupulously and in a manner which he could not but deeply feel, will ever redound to his credit, and prove him to have been that great philosopher which all his friends and adherents would wish to believe him. Do not mistake me, however, in one respect; there were times when he 'did well to be angry'; but his anger was slowly excited, and his occasional vehemence soon subsided into his wonted calm. More than all this, you will find that the childlike simplicity of his mind and the single-heartedness of his devotion to the study of Nature which characterised the beginning of his scientific career endured unto the end. His admission at the outset of 'utter ignorance whether I note the right facts'; his confession that he was 'nothing more than a lions' provider'; his unfeigned astonishment at discovering that his early observations were of any worth—are all of a piece with the humility he subsequently displayed when his success was declared. As he found, one after another, many of his contemporaries and still more of the younger generation of naturalists adopting his views, his joy was great; but that joy was not alloyed by any feeling of pride. He did not care for making a convert to 'Darwinism'—his exultation was that the strength of truth, of reason, and of observation had prevailed. In the same lowly spirit he, when at the height of his fame, expressed his gratitude to those, whosoever they might be, that helped him in his labours; and, if I might be critical on this point, I should say that his inherent goodness of heart often caused him to exaggerate the importance of the help they gave. Not a spark of jealousy was kindled in his mind; and at what may be considered the most trying moment of all, when the theory he had for twenty years been testing by every means in his power, the theory on which he built all his hopes of future recognition, the theory which he not unnaturally believed to be his peculiar possession—when this theory, I say, was independently conceived by another naturalist, his conduct was emphatically that of a man of honour. It pained him acutely to think that this naturalist, a trusted correspondent, an esteemed philosophical observer, and at the very time a wanderer far from home, should be deprived of the full glory of his ingenuity; and, but for the counsel of judicious friends (whose good advice on this occasion is indisputable), Mr. Darwin would have withdrawn every claim of his own to this great discovery, and left it entirely to Mr. Wallace! In the history of science and invention I think there are few cases like this. When you come to read the book you will find that though he unreservedly placed the matter in the hands of Sir Charles Lyell and of Sir Joseph Hooker, it was some time before he could reconcile himself to the notion that they were not unduly favouring him at the expense of his competitor. Such was the man! Though you are doubtless all aware of the fact, it would be wrong in me if I omitted to remind you that Mr. Wallace's conduct under these circum-

stances—sufficiently disappointing, as all must admit, to him—was in every way worthy of Mr. Darwin's. If in future you should meet with any cynic who may point the finger of scorn at the petty quarrels in which naturalists unfortunately at times engage, particularly in regard to the priority of their discoveries, you can always refer him to this greatest of all cases, where scientific rivalry not only did not interfere with, but even strengthened, the good-feeling which existed between two of the most original investigators.

I said but a few minutes since that it was fitting that the memoir of Mr. Darwin should appear this year—this year of jubilee—and a very remarkable anniversary I now have to point out to you. I learn from the Memoir that Mr. Darwin's pocket-book for 1837—just fifty years ago—has this entry:—

'In July opened first note-book on Transmutation of Species. Had been greatly struck from about the month of previous March on character of South American fossils, and species on Galapagos Archipelago. These facts (especially latter), origin of all my views.'

Other passages in his already published works confirm this memorandum; but we had not hitherto known with certainty when the views originated. We may now, therefore, celebrate among other jubilees that of Mr. Darwin's adopting the theory of the Origin of Species by Natural Selection, though I am bound to tell you that it was not until a few months later—about the beginning of 1838—that, after reading Malthus's work, the full conviction of the truth and sure ground of his speculative views came upon him.

I would not have my audience disperse with the impression that my business here is merely to point out what has been done by the genius of the great man of whose character and labours I have just been speaking. Enormous as are the strides which he has enabled us to make, you will all admit that it behoves us to follow in the paths he has indicated. We may depend upon it that what we know bears a very small proportion to that which we do not know, and I venture to recall your attention to that subject, which, as I have just said, was the origin of all his views. That subject is the Geographical Distribution of animals and plants, not only at the present time, but in bygone ages. As regards Botany, I do not dare in the presence of so many distinguished authorities to say more than this—that I believe the greatest and most important results of their labours in this direction are inadequately known to zoologists, while in Zoology I am certain that there are many large groups of whose distribution we are almost entirely ignorant.[1] That excellent work has been done in some groups all will admit, and in regard to the difficulties which have precluded the investigation of the subject in other groups I am well aware. But not only do we need further investigation in regard to them, we want much more correlation of results than we yet possess, and still more a comparison of the results obtained by botanical and zoological enquirers. Here there is a wide field, and a field worthy of cultivation. I do not know that a more competent body of cultivators can be found than within this section of the British Association, and if they can be persuaded to make common cause, the study of Biology will be much advanced. We have been told that it is as useless to investigate the origin of life as the origin of matter. That may be true or it may not; but it seems to me that to learn the way in which life has spread over the globe ought to be within the capacity of man, and we can hardly learn that way except by far more intercommunication of special knowledge than has hitherto been made. It is evident that with the existing minute subdivision of biological research the subject is beyond the power of any one man; but I should rejoice if anything I could say on this occasion might put in train some alliance between Botanists and Zoologists for the object I have just suggested. It may be said that we have not sufficient information as to certain parts of the world to enable such an alliance to effect its work satisfactorily.

[1] I say this after having studied Professor Heilprin's recent work, *The Geographical and Geological Distribution of Animals* (International Scientific Series, 1887)—in many respects the fullest on the subject—and also Mr. Helmsley's admirable *Introduction* to the Botany of the *Biologia Centrali-Americana*, which will shortly appear. The opportunity of reading the latter I owe to the kindness of Mr. Salvin.

If that be the case I am sure you will join with me in thinking that these insufficiently-known parts of the world should be subjected to a thorough biological exploration. For many years past I have been accustomed to hear an adage that 'Property has its duties as well as its rights.' If I am strongly in favour of the rights of property, I am no less prepared to exact from it its duties. Various events have given to this nation rights of property in many parts of the globe. I think we ought to justify those rights, and there is no better way of doing this than by performing the corresponding duties. It is incontestable that among the dependencies of the British Crown there are innumerable places—islands, large and small, territories the limits of which no geographer or diplomatist can define, and so forth—of which the fauna and flora have never been scientifically investigated. It is right, of course, that I should recognise the successful efforts made in many instances by the directorate of the Royal Gardens at Kew, and to a less extent by private persons. But why should not a properly organised biological investigation of all the portions of the empire be made? You will, I think, all agree that it is our duty to carry out investigations of this kind. Whether they would be better performed under the superintendence of Her Majesty's Government or not is a point on which I reserve my opinion, only mentioning that the success which has attended those instituted by the botanical authorities at Kew leads me to suppose that an extension of the method there followed might produce results as satisfactory; but, if this be the course adopted, I must point out that the organisation of a corresponding zoological and geological directorate will be needed. This matter I merely throw out for your consideration; but I would add that if anything is to be done no time is to be lost.

When on a former occasion (at Glasgow in 1876) I had the honour of addressing a Department of this Section, I pointed out the enormous changes that were swiftly and inevitably coming upon the fauna of many of our colonies. The fears I then expressed have been fully realised. I am told by Sir Walter Buller that in New Zealand one may now live for weeks and months without seeing a single example of its indigenous birds, all of which, in the more settled districts, have been supplanted by the aliens that have been imported; while further inland these last are daily extending their range at the cost of the endemic forms. A letter I have lately received from Sir James Hector wholly confirms this statement, and I would ask you to bear in mind that these indigenous species are, with scarcely an exception, peculiar to that country, and, from every scientific point of view, of the most instructive character. They supply a link with the past that once lost can never be recovered. It is therefore incumbent upon us to know all we can about them before they vanish. I have particularly instanced birds because I happen to have studied them most; but pray do not imagine that the same process of extirpation is not extending to all other classes of animals, or that I take less interest in their fate. The forms that we are allowing to be killed off, being almost without exception ancient forms, are just those that will teach us more of the way in which life has spread over the globe than any other recent forms, and for the sake of posterity, as well as to escape its reproach, we ought to learn all we can about them before they go hence and are no more seen.

I have just now applied to these expiring forms of New Zealand the epithet ancient, and in connexion therewith I would, by way of conclusion, offer a few remarks on the aspect which the subject of Geographical Distribution presents to me. Some of us zoologists—I am conscious of having myself been guilty of what I am about to condemn—have been apt to speak of Zoological Regions as if they were, and always had been, fixed areas. I am persuaded that if we do this we fall into an error as grievous as that of our predecessors, who venerated the fixity of Species. One of the best tests of a biologist is his being able to talk or write of 'Species' without believing that the term is more than a convenient counter for the exchange of ideas. In the same way I hold that a good biologist should talk or write of 'Zoological Regions.' The expression no doubt arose out of the belief, now scouted by all, in Centres of Creation; and, as sometimes used, the vice of its birth still clings to it. To my mind the true meaning of the phrase 'Zoological Region' is that of an area inhabited by a fauna which is, so to speak, a 'function'

of the period of its development and prevalence over a great part of the habitable globe, but at any rate of the period of its reaching the portion of the earth's surface where we now find it. One great thing to guard against is the presumption that the fauna originated within its present area and has been always contained therein. Thus I take it that the fauna which characterises the New-Zealand Region—for I follow Professor Huxley in holding that a Region it is fully entitled to be called—is the comparatively-little changed relic and representative of an early fauna of much wider range; that the characteristic fauna of the Australian Region exhibits in the same way that of a later period: and that of the Neotropical Region of one later still. But while the first two Regions have each been so long isolated that a large proportion of their fauna remains essentially unaltered, the last has never been so completely severed, and has received, doubtless from the north, an infusion of more recent and therefore stronger forms; while, perhaps impelled by the rivalry of these stronger forms, the weaker have blossomed, as it were, into the richness and variety which so eminently characterise the animal products of Central and South America. I make no attempt to connect these changes with geological events, but they will doubtless one day be explained geologically. It is not difficult to conceive that North America was once inhabited by the ancestors of a large proportion of the present Neotropical fauna, and that the latter was wholly, or almost wholly, thrust forth—perhaps by glacial action, perhaps by the incursion of stronger forms from Asia. The small admixture of Neotropical forms that now occur in North America may have been survivors of this period of stress, or they may be the descendants of the more ancient forms resuming their lost inheritance. Beyond the fact that these few Neotropical forms continue to exist in North America, its fauna seems to be in a broad sense inseparable from that of the Palæarctic area, and, in my belief, is not to be separated from it. The most difficult problems are those connected with the Ethiopian and Indian (which Mr. Wallace calls the Oriental) areas; but I suppose we must regard them as offshoots from a somewhat earlier condition of the great northern or 'Holarctic' fauna, and as such to represent a state of things that once existed in Europe and the greater part of Asia. To pursue this subject—one of most pleasing speculation—would now be impossible. I pray you to pardon my prolixity, and I have done.

The following Reports and Papers were read:—

1. *Report of the Committee on Migration.*—See Reports, p. 70.

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2. *Report of the Committee on the Fauna and Flora of the Cameroons Mountains.*—See Reports, p. 73.

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3. *Report of the Committee to arrange for the Occupation of a Table at the Zoological Station at Naples.*—See Reports, p. 77.

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4. *Report of the Committee on the Zoological Station at Granton.*—See Reports, p. 91.

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5. *Report of the Committee on the Marine Biological Association Laboratory at Plymouth.*—See Reports, p. 59.

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6. *The Exploration of Liverpool Bay and the Neighbouring Parts of the Irish Sea by the Liverpool Marine Biology Committee. By* Professor W. A. Herdman, *D.Sc., F.L.S.*

The work which the L. M. B. C. have set before them is the thorough investigation of the fauna and flora of Liverpool Bay. Their aim is not merely to draw

up an accurate list of the species found in this locality, but also to observe and record the relative numbers, the size, the colours, and the conditions generally of the specimens, the exact localities in which they are found, the other species of animals and plants associated with them, and their mutual relations as food, enemies, or competitors. In this way it is hoped that a mass of observations will be accumulated which may be of use in determining the geographical distribution of species, the nature of the conditions which influence species, and the relations existing between various plants and animals.

The operations of the Committee have been carried on now for three seasons, and have consisted of dredging expeditions—lasting in some cases for several days at a time—tow-netting expeditions in small boats, and shore expeditions for the investigation of the littoral fauna. A considerable extent of the large quadrangular area[1] of the Irish Sea, extending around Liverpool Bay and bounded by the Isle of Man and the coasts of Anglesey, North Wales, Cheshire, and Lancashire, has now been explored, large collections have been made, and a first volume of reports has been published; but the Committee feel that their work will be a matter of time, and that they must carry on their observations for a number of years before they can be in a position to draw conclusions in regard to the fauna they are investigating. In the meantime they are completing the local lists of species, and they are recording the exact localities of the specimens they collect, so as to provide the means for detecting any changes in the fauna which may take place in the future.

A careful record of the habits of the moving animals, such as mollusca, is also a part of the work of the L. M. B. C.

In order to make such observations and for various other purposes it is necessary to study carefully limited regions in the district and to be able when necessary to keep some species in captivity. The Committee have therefore during the present summer established a small observing station or marine laboratory on the north-east end of Puffin Island, near Anglesey. The shores of the island are rocky and support an abundant fauna, and good dredging-ground is present in the immediate vicinity. Altogether the Committee feel that this station, if they can afford to keep it up, ought to be of very great service to them in carrying on their work.

The object of this paper is merely to give a general idea of the objects and the plans of work of the Committee, for all further particulars reference must be made to the detailed reports which they are publishing;[2] while those members of the British Association who take part in the dredging expedition on Saturday, Sept. 3, will have an opportunity of inspecting the biological station on Puffin Island and of making a practical acquaintance with the fauna of Liverpool Bay.

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7. *On some Copepoda new to Britain found in Liverpool Bay.*[3] *By* Isaac C. Thompson, *F.R.M.S.*

The paper supplemented one recording a considerable number of species of Copepoda new to the district, and itself deals with several species, altogether new to Britain, found in Liverpool Bay.

The first alluded to is the *Eurytemora hirundo*, taken on two separate occasions by the tow net in the Crosby Channel, and hitherto recorded by Giesbrecht as occurring in one district of the Baltic. In general appearance it resembles the well-known *Temora longicornis* of our seas, but the points of divergence are considered by Giesbrecht sufficient to bring about a division of the genus *Temora* into the sub-genera *Eurytemora* and *Halitemora*.

Dias discaudatus is another form, new to Britain, found by the author in

[1] Generally called for short in the Reports, the L. M. B. C. district.

[2] The first volume of these (*Fauna of Liverpool Bay*, Longmans, 1886) has already appeared. Future reports will be published in the *Proceedings of the Liverpool Biological Society*.

[3] Original paper is published in vol. i. *Transactions of Liverpool Biological Society*, 1887.

Liverpool Bay, though from its general resemblance to *Dias longiremis* he considers it probable that it may have been previously overlooked, the points of difference, though important, being only distinguished by careful microscopical examination.

Pontella Wollastoni, first described by Sir John Lubbock in 1857, from specimens taken by him at Weymouth, has not since been recorded as occurring in British waters until now found in Liverpool Bay. This and the previously named Copepoda were illustrated by drawings taken from specimens freshly preserved.

In conclusion the author stated: The presence and distribution of Copepoda in our seas are most vitally interesting, forming as they unquestionably do by far the largest proportion of the life of the ocean. And being themselves of the utmost purifying utility as refuse-gatherers, they transform the same by their internal biological and chemical laboratories into food for higher orders of pelagic denizens, these again furnishing in illimitable quantity the food of man.

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8. *Marine Zoology in Banka Strait, North Celebes.* *By* SIDNEY J. HICKSON, *M.A.*

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9. *Proposed Contributions to the Theory of Variation.* *By* PATRICK GEDDES.

With reference to a forthcoming more extended discussion of the laws of variation (in the article Variation and Selection of the 'Encyclopædia Britannica' and elsewhere) the writer desires to submit for discussion (1) an hypothesis of the internal mechanism of variation in terms of the familiar antagonism between vegetation and reproduction, this being treated especially in its bearing on the physiology, morphology, and natural classification of plants; (2) a kindred hypothesis, but treated with special reference to the animal kingdom, which endeavours to account (1) for the variations in bulk (2), for at least many cases of the extinction of species.

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10. *On the Early Stages in the Development of* Antedon Rosacea. *By* H. BURY, *B.A.*, *F.L.S.*

Segmentation is regular. The mesoderm is not formed until after the invagination of the archenteron, and arises solely from the latter and its derivatives. Immediately after the closure of the blastopore the archenteron splits into two halves: (1) anterior, becomes constricted in the middle and soon divides completely into the right and left body-cavities; (2) posterior, gives rise to three cavities—(*a*) the gut which forms a ring round the constricted part of the peritoneal vesicle; (*b*) the hydrocele on the right-hand side; (*c*) an unpaired posterior body-cavity.

The 'yellow cells' appear before the larva is free.

The free larva has five ciliated bands, the posterior one being incomplete ventrally. The right and left body-cavities are now anterior and posterior respectively: the left body-cavity forms five longitudinal chambers in the stem; the hydrocele forms an incomplete ring on the ventral side of the gut: and the unpaired body-cavity opens to the exterior by a pore (water-pore) on the right-hand side.

The larva now fixes itself by the 'pseudoproct.' The 'pseudostome' invaginates and becomes rotated round to the anterior end, where it forms the tentacular cavity. The right and left body-cavities grow round to the ventral surface, and there form two longitudinal mesenteries; in the anterior of these the stone canal depends from the water-vascular ring, and opens into the unpaired body-cavity, which is now quite small.

The anus subsequently opens (with rare exceptions) in the same interradius as the stone canal.

Skeleton.—At the top of the stem three underbasals are formed, the smallest of which is situated in the left dorsal radius, *i.e.*, just opposite the anal interradius.

These three plates soon fuse together and with the top stem joint, and they thus form the angles of the large plate, hitherto mistaken for a simple centrodorsal.

From a comparison of the development of antedon with that of other Echinoderms it seems almost certain that, as Barrois has suggested, the stalk represents the præoral lobe.

11. *On the True Nature and Function of the Madreporic System in Echinodermata.* *By* Dr. M. Hartog.

This, always regarded hitherto as an apparatus for taking up sea-water, is now shown to be excretory; for the following reasons:—

1. *Physiological.*—An animal with a central cavity, or series of cavities, containing dissolved in their liquid substances of osmotic attraction, must tend to turgesce like a vegetable cell, and hence require some apparatus to eliminate the excess of liquid. This is provided by the nephridial system with its ciliated nephrostomes in most animals. The only organ that can have this function in echinodermata is the madreporic canal and plate.

2. *Morphological.*—The madreporic system, ontogenetically formed of an endothelial sac opening through an epilelastic invagination, is equivalent to an Annelid nephridium.

3. *Comparative.*—In most Holothurians the respiratory trees are sufficient to expel the excess of water, and the madreporites have lost direct connection with the outside; in the Elasipoda, where the trees are absent, the madreporite opens on the surface.

4. *Demonstrative.*—In *Echinus sphæra* the ciliary current in the madreporic canal is *seen* to carry suspended bodies towards the plate, and this is the true test of the direction of ciliary currents.

To meet the objection as to how enough liquid was supplied for a general erection of the tube feet, I would suggest that a slight dilatation of the cavity of the gut, freely taking up sea-water, would compensate for the withdrawal of liquid from the ampullæ.

FRIDAY, SEPTEMBER 2.

The following Papers were read:—

1. *Discussion in conjunction with Section C on the 'Arrangement of Museums.'*

2. *On the Vascular System and Colour of Arthropods and Molluscs.* *By* Professor Lankester.

3. *Notes on the Genus* Phymosoma. *By* W. F. R. Weldon.

4. *On the Degeneration of the Olfactry Organ of certain Fishes.* *By* Professor Wiedersheim.[1]

It has been shown by Johannes Müller that an olfactory organ similar to that of other fishes is wanting in many species of the genus *Tetrodon*, but that in its place there is on either side of the head a solid tentacle-like process of the skin, into which the olfactory nerve extends. This is all that until now was known on the subject.

Having, however, recently looked into the matter, I am able to give the following short account of my results.

[1] Published in the *Festschrift zu Koelliker's 70ten Geburtstag.* Leipzig, 1887.

In *Tetrodon hispidus, immaculatus* and *nigropunctatus*, a tentacle-like process of the skin is present on either side of the head, between the snout and the eye, the base of which is surrounded by a narrow circular fold, while distally it becomes forked so as to form two broad divergent lamellae. The surfaces of these two lamellae which are turned towards one another, are pigmented, and are covered over by a network of delicate ridges, in the meshes of which the sensory organs lie. The outer surfaces of the lamellae are smooth.

Somewhat behind the middle line of the internal wall of the orbit, the exceedingly delicate olfactory nerve passes out of the skull-wall. Directly after its exit, it becomes surrounded by a thick fibrous sheath, which protects it from the movements of the eyeball and its muscles.

After passing over the superior oblique muscle, the nerve comes to lie dorsally to the well-developed muscles of the jaws, being closely jammed in between these and the wall of the skull. At the same time it is protected from the pressure of the masticatory muscles by a dense fibrous plate.

From this point, instead of passing to the base of an olfactory sac, it extends directly outwards into the skin, and thence into the above-described cylindrical nasal process; within this it branches out into a series of twigs arranged in a circle around the longitudinal axis of the process.

These nerve-twigs extend throughout each lamella, and pass outwards into the sensory cells, the arrangement of which is exactly similar to that of segmental sense organs in the skin of fishes.

The olfactory organ of *Tetrodon papua* is of special interest, inasmuch as it has undergone a very considerable degeneration. No trace of projecting nasal folds can be seen, and for some time I thought that a nasal organ was quite wanting in this fish. Indeed, from a physiological point of view, this is very likely the case, but if the brain be examined, the olfactory nerves can be distinguished by the aid of a lens. They have the form of hair-like threads, the relations of which to the orbit and to the muscles of the jaws are quite similar to those I have described above in the case of other *Tetrodonts*. Instead, however, of branching out into a process of the skin, they end on a level with the general surface of the integument, which shows at this point a small pigment-spot. If I had not carefully followed out the course of the olfactory nerve, this spot would have escaped my notice, for the skin of the head is provided with numerous similar pigment-spots in this region. I cannot state with certainty whether a neuro-epithelium was present, as the specimen was not sufficiently well preserved for histological examination.

Besides the species of *Tetrodon* already named, I have also examined *Tetrodon pardalis* and *Diodon maculatus*. In both of these, nasal processes are also present, having the form of blunt cones. Instead, however, of being solid, they are hollow, the enclosed cavity communicating with the exterior by two apertures, through which a current of water can pass as the fish moves about.

The lining-wall of the cavity is raised into a number of fold-like processes, the arrangement of which is similar to that of the valves in the *conus arteriosus* of certain fishes; in this way a large surface is produced for the sensory organs.

As in the forms already described, a proper olfactory sac is wanting, and the olfactory nerve passes directly towards the outer skin, finally ending in the nasal processes.

These observations lead me to the following conclusions:—

The peculiar structure of the olfactory organ in the genus *Tetrodon* cannot be looked upon as primitive, but must have arisen secondarily. *Tetrodonts* must formerly have possessed a proper olfactory sac, more or less deeply sunk into the skull. Moreover, this sac was provided with a membranous tube leading to the exterior, similar to that present in *Muraenoids, Polypterus,* and many other fishes.

In the course of phylogenetic development, as the *Tetrodonts* began to browse upon corals and hard shells of mollusks, the masticatory muscles must have undergone a correspondingly strong development. In consequence of this, the points of origin of these muscles extended further and further over the anterior part of the skull, and passed upwards between the snout and eyes. Thus they gradually replaced the olfactory sac, which was formerly present in this region; while the

external nasal tube persisted, although in modified form. The olfactory nerve, gradually decreasing in size, became at the same time pushed outwards until it reached the level of the skin.

Thus the condition of things seen in *Tetrodon pardalis* and *Diodon maculatus* was reached. The *Schneiderian* folds formerly present in the olfactory sac were then replaced by the above-described processes on the inner wall of the nasal folds.

The hollow olfactory tube may be considered as a protective arrangement for the nerve end-organs, but its structure became changed in the course of phylogenesis. As the two apertures in its wall gradually became elongated, so as to reach to the distal end, they eventually caused a splitting of the nasal process into two solid limbs.

This stage is represented by *Tetrodon nigropunctatus, immaculatus,* and *hispidus,* while a still further regressive development of the organ has taken place in *Tetrodon papua,* in which the last stage of the whole process is reached.

It is not impossible that species of *Tetrodonts* exist in which a still further degeneration has taken place, so as to cause an entire disappearance of the olfactory nerve.

These facts seem to me to have a still further interest inasmuch as they show that the olfactory organ, as well as the eye of vertebrates (compare *Gymnophiona, Proteus, Amblyopsis,* &c.), may pass into an unstable condition, should it become necessary in the interest of the animal as a whole.

Further histological researches must show whether this peculiarly modified nasal organ in *Tetrodonts* is still physiologically an *olfactory organ,* or whether it has undergone a change of function.

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5. *On the Torpid State of* Protopterus. *By* Professor WIEDERSHEIM.[1]

In July last I received some living specimens of *Protopterus,* from the river Gambia, which had been taken during the torpid period and sent to this country, still enclosed within clods of earth. One of them had been set free on the previous day, while two clods were still intact.

In both of the latter, as previously described by Mr. Bartlett, a round aperture could be seen, leading into a smooth-walled tube about 15 centimètres in length. Only one of the clods, however, was found to contain a specimen; from the other the animal had already escaped.

In opening up the clod I intentionally followed a different method from that of my predecessors, all of whom without exception set free the animal by softening the earth in water.

Although this is undoubtedly the most delicate method of operation, it renders it impossible to see the animal undisturbed in its natural position within the enclosing capsule or so-called *cocoon.*

I therefore carefully broke away the earth, bit by bit, with a hammer and chisel till the dark-brown capsule was exposed. This latter was of a tolerably regular oval form except in that region where the tube abutted against it. In this place it was flattened and oblique in position, reminding one of the human tympanic membrane. This does not correspond with Bartlett's description, but my observations closely agree with those of Krauss on this point.

I cannot be certain whether this flattened portion of the capsule was perforated by an aperture, as described by former observers; but it seems to me to be in the highest degree probable that such an aperture was present, inasmuch as the snout of the animal was closely pressed into the acute angle formed between the flattened membrane and the rest of the capsule wall.

I have nothing to add to Krauss's description of the enclosing membrane, but I hope shortly to be able to give an account of its chemical nature, which is being determined by my friend Professor Baumann, of Freiburg.

It may, however, be stated with certainty that the capsule consists of a

[1] Published in the *Anatomischer Anzeiger.* Jena, 1887.

hardened secretion, but how and where this secretion, or perhaps better, excretion is formed is not known.

A clear, glistening substance of varnish-like consistency, which covers the torpid animal within the capsule and keeps it moist is probably of the same nature. This calls to mind the arrangement for protecting the young in *Epicrium* described by the two Sarasins.

The hard external covering may also partially perform a similar function, but it serves chiefly to protect the animal from compression during the gradual contraction of the enclosing earth in drying.

Günther has observed a mucus-secreting apparatus in *Ceratodus*, which opens to the exterior near the articulation of the lower jaw, but it is not known whether a similar structure is present in *Protopterus*.

The position of the animal during its long period of torpor is very peculiar, and, as I believe, has not yet been described. I add the following exact details. At first sight it is impossible to distinguish the different regions of the body, the animal simply appearing like a mass of irregular form, the spaces between its individual parts being filled up by the glairy secretion.

With careful examination, however, it is possible to distinguish the snout, which is enclosed by a broad membrane covering the whole head like a veil. This membrane, which is covered with spots of pigment, is the broad tail-fin, which, gradually narowing as it passes backwards, ends in a whip-lash-like filament.

This caudal filament lies close against the left side of the body, near the point of origin of the hinder extremity, and from here it becomes curved upwards towards the anterior boundary of the dorsal fin. At this point the body is sharply bent on itself towards the right side, and the angle thus formed corresponds to the position of the filament described by Bartlett as arising from the capsule and passing through its entire diameter from above downwards.

The body then curves forwards and passes into the tail, which, as already described, covers the head and anterior part of the trunk. The ends of the two anterior extremities project forwards like the 'horns' of a snail between the snout and the overlying dorsal fin.

During the removal of the capsule the animal remained perfectly motionless, and only began to move convulsively on being irritated.

After being put into water an hour passed before the animal was completely unrolled, and during this time the glairy mucus was drawn out into white threads.

At first the head was gradually pushed out from under the tail-fin, the movements being very slow, and reminding one of the manner in which a snail extends itself out of its shell.

This is the only possible method for the animal to begin unrolling itself, for the caudal filament is so firmly fixed to the body-wall that it can only be loosened after the whole of the rest of the body is set free.

Soon afterwards bubbles of air, and then water, could be seen passing out of the gill-opening, and then the animal began to swim about, seeming at once to be quite at home in the water.

Both specimens are still living in the Anatomical Institute at Freiburg.

In conclusion I must mention two circumstances in connection with the physiology of *Protopterus* during its torpid state, which seem to me of great interest.

In the neighbourhood of the snout I found a soft greyish-white mass, which had evidently been excreted by the animal. This resembled the excretion of birds and reptiles, and I have no doubt that it is to be explained in the same way, and that the vital functions of the animal go on slowly during the whole period of torpor. As this mass is deposited close to the small aperture in the capsule, it is very probable that the latter serves to conduct it to the exterior.

I cannot decide with certainty whether this aperture, as former observers have supposed, serves also for respiration, but I am able to show that *Protopterus possesses a special respiratory organ in its broad tail-fin.*

Over the head and for some distance backwards, where it lies close against the external wall of the capsule, *the tail-fin was of a bright red colour*, and an examina-

tion with a lens showed it to be richly provided with distended blood-vessels. The colour became momentarily still brighter when the capsule was removed.

There can be little doubt that the wall of the capsule in this region is permeable, and that the necessary interchange of gases can therefore take place through it.

This condition of things is similar to that seen in a frog from the Antilles, *Hylodes martinicensis*, in which also the broad tail-fin serves as a respiratory organ. Probably the same thing occurs in the larva of *Pipa*; and I may also call attention to another frog, found in Solomon's Islands, *Rana opisthodon*, in which a row of about nine transverse folds of the skin of the abdomen serve for respiration.

According then to my observations, *Protopterus* has *three means of respiration*, and it would be interesting to discover in what relative importance the lungs and the tail stand to one another in respiration during the torpid period. This would be all the more interesting inasmuch as various observers differ greatly in their descriptions of the pulmonary circulation of the *Dipnoi*.

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6. *The Larynx and Stomach of Cetacean Embryos.* *By* Professor D'Arcy Thompson.

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7. *On* Haplodiscus Piger. *By* W. F. R. Weldon, *M.A., Fellow of St. John's College, Cambridge.*

The name *Haplodiscus* is proposed for a small pelagic organism found by the author in the Bahama Islands. It is a discoidal animal, about two millimètres in diameter, convex dorsally and concave ventrally. The body is covered by a cuticle, and is not ciliated. Within the cuticle is a continuous tunic of nucleated protoplasm, in which cell-outlines are not distinguishable, and which sends anastomosing processes through the cavity of the body. In the centre is a solid mass of protoplasm, continuous laterally with the general somatic reticulum, and communicating with the exterior by a small slit on the ventral surface, through which it can probably be partially extruded in the form of pseudopodia. This central protoplasmic mass is the alimentary tract, and generally contains numerous 'food-vacuoles,' in which are imbedded the remains of various organisms such as copepods, &c.

At the anterior edge of the body is a brain, with a short nerve cord extending from it on each side.

Reproduction is effected by means of ova and spermatozoa, the animals being hermaphrodite. The ovaries lie one on each side of the mouth; the single testis is situated in the middle dorsal line. The male genital opening is median and posterior; no female opening was observed.

Yellow cells are plentifully scattered through all the tissues.

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8. *The Blood-corpuscles of the* Cyclostomata. *By* Professor D'Arcy Thompson.

Sub-Section BOTANY.

1. *Report on the Disappearance of Native Plants.*—See Reports, p. 130.

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2. *Report of the China Flora Committee.*—See Reports, p. 94.

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3. *Cocoa-nut Pearls.* *By* S. J. Hickson.

4. *Note on the Nitrogenous Nutrition of the Bean.* *By* S. H. VINES, *D.Sc., F.R.S.*

[Preliminary communication.]

I give here the results of some observations on water-cultures of the bean (*Vicia faba*) as a contribution to a subject which has already been much discussed, but without any generally accepted decision having been arrived at.

It is generally admitted that a leguminous crop does not impoverish the soil as regards combined nitrogen but rather enriches it. It occurred to me to observe the effect of growing beans in solutions, some of which did and some of which did not contain combined nitrogen.

Young bean-plants, about a week or ten days old, were placed, on June 25, 1887, with their roots in the following solutions (three in solution I., three in solution II.):—

Solution I.

	Grms.
Distilled water . .	1,000·00
Potassium nitrate . .	1·00
Calcium sulphate . .	0·50
Magnesium „ . .	0·50
Calcium phosphate .	0·25

Solution II.

	Grms.
Distilled water . .	1,000·00
Potassium phosphate .	·50
„ chloride .	·50
Calcium sulphate . .	·50
Magnesium „ . .	·50
Calcium phosphate .	·25

Analysis of solution II. showed that no combined nitrogen, other than a trace of free ammonia, was present.

After being ten days in the water-culture the cotyledons were removed from two plants of I. and II. respectively.

The plants all grew well, but those in solution II. grew better than those in I.; they all flowered, but in no case, possibly owing to non-fertilisation, was any seed formed.

After flowering, the plants began to dry up: the experiment was closed on August 12.

After the removal of the plants the liquid in the six pots was examined. The liquid in the three pots of II. was turbid and of putrescent odour, whereas that in the three pots I. was comparatively free from turbidity and from smell. The turbidity in pots II. was largely due to bacteria.

For the purpose of tabulation the pots may be distinguished thus:—

$\left.\begin{array}{l} I._1 \\ II._1 \end{array}\right\}$ with Cotyledons.

$\left.\begin{array}{l} I._2 \\ II._2 \\ I._3 \\ II._3 \end{array}\right\}$ without Cotyledons.

They were examined qualitatively for ammonia and albuminoid nitrogen, and quantitatively for nitrates. No nitrites were found.

	$I._1$	$II._1$	$I._2$	$II._2$	$I._3$	$II._3$	
Ammonia .	Trace	Trace	Trace	Strong	Trace	Strong	
Nitrates .	5·51	Absent	4·35	Absent	4·36	Absent	Milligrms. in 100 cc.
Albuminoid Nitrogen .	Present	Present	Present	Present	Present	Present	

The solutions $I._1$, $I._2$, $I._3$, each contained originally 14 mgrs. N in 100 cc. It will be noticed that rather less of the combined nitrogen supplied was absorbed by the plant which retained its cotyledons than by those which were deprived of them. The general result of the experiment seems to indicate that a bean-plant can obtain supplies of nitrogen even when growing in a soil in which no combined nitrogen is originally present.

It may, however, be objected that plants II_2 and II_3 which retained their

cotyledons for ten days in the water-culture absorbed from them sufficient combined nitrogen for their nutrition during the whole period, and to account for the combined nitrogen present in the liquid after the close of the experiment. This objection does not seem to be a strong one, but the point cannot be regarded as finally settled until exact quantitative determinations of the nitrogen in the seed, in the plant, and in the water have been made. This I hope to do in another series of experiments.

On removing the plants from the solutions at the close of the experiment I was struck by certain differences in the roots of those grown in solutions I. and II. The roots of the plants grown in solution I. were short and thick, and were entirely destitute of those tubercles which so commonly occur on the roots of *Leguminosæ*; whereas those of the plants grown in solution II. were long and slender, and bore a great number of tubercles. The tubercles were present on the roots both in and out of the liquid.

As I only examined the tubercles when the plants were drying up I am unable to say anything as to their mode of origin or as to their normal structure. I may mention one point—that in many cases the contents of the tubercle had been extruded, leaving a delicate sac, traversed by vascular tissue, attached to the root.

The concurrence of abundant tubercles on the roots of Leguminosæ with a deficiency of combined nitrogen in the soil has already been dwelt upon by De Vries and others; but the constancy of this correlation has been denied. My own observations lead me to support De Vries' view. I cannot but regard these tubercles as of great importance in the nutrition of the plant. They are not mere depositories of proteid substances, as is urged by Tschirch and others, for they are far too small to be of any significance in this direction. Moreover the structure of the cells, when active, is not that of depositories. They are full of granular protoplasm, including the peculiar 'bacterioid' bodies which have been detected in them; but there does not appear to be any masses of dead proteid resembling the aleurone-grains of seeds. Judging from the published figures of sections of active tubercles the 'bacterioid' tissue suggests the actively metabolic tissue of a gland. The question is, What is the nature of their metabolic activity? Do they assimilate free nitrogen, or do they simply assimilate combined nitrogen formed in the soil (or solution) by bacteria? I am inclined to conclude that the former is the case, but my observations do not warrant a definite decision on this point. I hope to arrive at it by further experiment.

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5. *On the Movement of the Leaf of* Mimosa Pudica. *By* S. H. Vines, *D.Sc., F.R.S.*

[Preliminary communication.]

The special object in view was to obtain some further information as to the nature of the mechanism of the movements of the leaf. With this object experiments were made to ascertain the nature of the effects produced with atropin and physostigmin—alkaloids which are known to produce well-marked effects in the animal body.

Branches of Mimosa were cut off under water and were transferred to watery solutions of the alkaloids. The salts used were tartrate of atropin and citrate of physostigmin; the solutions were made faintly acid with citric acid.

Various strengths of solution were tried, but the most gradual, and therefore most instructive, results were obtained with solutions of 0·25 per cent. The quantity of solution used was 10 cc., but in no case was more than 2 or 3 cc. absorbed during the experiment, which extended over 24 to 30 hours.

Effect of atropin:—

a. *On the main pulvinus.*—The movement of the petiole on stimulation becomes gradually less and less, until movement ceases altogether, the petiole retaining the more or less nearly horizontal diurnal position.

b. *On the leaflets.*—The induced movement of the leaflets is at first well marked, and they readily recover the expanded position; but gradually

they fail to expand completely after stimulation, until at length they remain completely closed.

Effect of physostigmin:—

a. *On the main pulvinus.*—The effect is gradually to diminish the extent of the recovery of the pulvinus after stimulation, until eventually the pulvinus retains the position characteristic of stimulation.

b. *On the leaflets.*—The closing movement on stimulation becomes less and less marked, until finally they make no movement at all, but remain open.

Explanation of results.—These results are readily intelligible when they are considered in connection with the effect of the normal alternation of day and night. From the researches of Brücke and of Millardet it is known that the tension in the plant as a whole—that is, the state of expansion of its cells—diminishes during the day and increases during the night. The closing of the leaflets when evening comes on is the result of the commencing increase of tension or expansion. The petiole also rises in the evening, as Pfeffer has shown, when the leaflets and secondary petioles are removed; but when these are present the petiole is mechanically depressed for a time, though even then it rises during the night. The leaflets remain closed during the night. During the day the leaflets remain open, and the petiole sinks to a more or less nearly horizontal position.

The effect of atropin is just that of darkness; it causes the leaflets to close and the petiole to maintain a horizontal position, even when stimulated—that is to say, it promotes the tension, or expansion, of the cells.

Physostigmin, on the contrary, causes a diminution in the state or expansion—or, in other words, a state of contraction—as is indicated by the position taken up by the leaflets and by the petiole under its influence. Its effect is similar to that of light.

It must be borne in mind that, inasmuch as these observations were made during the day-time, the effect of light must be taken into consideration. The effect of light is antagonistic to that of atropin, but it coincides with that of physostigmin. Hence the effect of atropin is not so marked as it probably would be in darkness.

It was found possible to cause the atropin position to be replaced by the physostigmin position by transferring a branch from one solution to the other.

The conclusion to be drawn is that it is the protoplasm which is the active agent in the movement of the leaves, and not either the cell-wall or the cell-sap. It is not conceivable that either the physical properties of the cell-wall or the osmotic properties of the cell-sap should be affected in such opposite ways by these alkaloids.

Whilst making the above observations I noted some points which are of general importance in the physiology of the movements of the leaves of Mimosa, and which appear to have been overlooked in the descriptions given of the movements under various conditions:—

1. The fall of the petiole is in no case caused by artificial darkness during the day-time, but takes place only in the evening when the general tension diminishes.

2. The secondary petioles are likewise unaffected by darkness during the day-time, and converge only in the evening. Their movement is dependent on the general diminution of tension.

3. The secondary petioles are sensitive to mechanical stimulation only when the leaf is young.

6. *On Flagella of Calamus. By* Professor F. O. Bower.

7. *Note on the Stomata and Ligules of Selaginella. By* Professor McNab, *M.D., F.L.S.*

At the meeting of the Dublin Microscopical Club on March 20, 1884, the author exhibited leaves of *Selaginella densa,* Hort. Sim., and *S. Poulteri,* Hort.

Veitch., showing a triple series of stomata developed along each margin. On recently examining the leaves of seedling plants of *S. Kraussiana* the peculiar marginal stomata were also found to be present. The stomata are usually developed close to the midrib of the leaf, on one, rarely on both sides; but the special marginal stomata to which the author directed attention form three rows, one on the actual edge of the leaf and one on the upper, another on the under side. In many species the margin of the leaf is occupied by a series of elongated sclerous cells; but in the three species above mentioned these cells are wanting. The marginal stomata are easily demonstrated with carbolic acid, which renders the whole part exceedingly transparent. In such transparent specimens the course of the fibro-vascular bundles can be readily traced, and the relation of the ligule to the bundle clearly made out. The bundle is slightly dilated by the addition of two or three tracheides just below the base of the ligule, and the author suggests that the ligule is probably an organ of absorption.

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8. *On the Adventitious Buds on the Leaves of* Lachenalia pendula. *By* Professor McNab, *M.D., F.L.S.*

The author exhibited a leaf of *Lachenalia pendula gigantea* from the Royal Botanic Garden, Glasnevin, with three adventitious buds close to the base and an inflorescence of *Lachenalia orchioides,* with a bulb in the scape some distance below the first flower of the raceme. Adventitious buds on leaves of monocotyledons are rare, but occur on *Hyacinthus fastigiatus* (Pouzolzii), *Ornithogalum thyrsoides, Eucomis regia, Atherurus ternatus,* and *Malaxis paludosa.* The buds on both the species of *Lachenalia* were first noticed by Mr. F. W. Moore, the Curator of Glasnevin Garden, to whom the author was indebted for the specimens exhibited.

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9. *On the Root-spines of* Acanthorhiza aculeata, H. Wendl. *By* Professor McNab, *M.D., F.L.S.*

The author exhibited two photographs of the stem of the Mexican palm, *Acanthorhiza aculeata* growing in the palm-house in the Royal Botanic Garden, Glasnevin, Dublin. The upper part of the stem and bases of the leaves were covered with the remarkable erect root-spines which characterise the genus. The apogeotropic nature of the aërial roots is specially remarkable, and the slender erect main spine contrasts with the thick descending roots which fix the stem to the soil. *Iriartea ferox* also possesses erect root-spines, while in the figure of *Acanthorhiza Warcewiczii* (Flora Brasiliensis, pl. 132) the spines are spreading or depressed. The structure of these roots, and the absence of root-caps, has been described by Friedrich in the 'Acta Horti Petropolitani,' vol. vii. p. 535.

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10. *On the Gramineous Herbage of Water Meadows.*[1] *By* Professor W. Fream, *B.Sc., F.L.S., F.G.S.*

The land on either side of the river Avon, flowing southward through Wiltshire and South Hants to enter the sea at Christchurch, is extensively laid out in water-meadows, of which the soil and the system of irrigation are described. The flora of these meadows is interesting, inasmuch as it is the result of a long-continued uniformity of conditions, the intermittent system of flooding rendering the area practically independent of variations in the rainfall, and to some extent counteracting the influence of extremes of temperature.

The herbage is more exclusively gramineous than is the case on ordinary meadow land. There are at least sixty non-gramineous species, which are thus distributed:—*Thalamifloræ* 8, *Calycifloræ* 15, *Corollifloræ* 27, *Incompletæ* 5, *Monocotyledones* 5.

[1] Published *in extenso* in the *Land Agents' Record.*

The grasses comprise the following 26 species:—

Phalaris arundinacea, L.	**Briza media*, L.
**Anthoxanthum odoratum*, L.	*Poa annua*, L.
Alopecurus geniculatus, L.	**Poa pratensis*, L.
**Alopecurus pratensis*, L.	**Poa trivialis*, L.
Phleum pratense, L.	*Glyceria aquatica*, Sm.
Agrostis alba, L.	*Glyceria fluitans*, Br., et var
**Agrostis vulgaris*, With.	*Festuca duriuscula*, L.
Aira cæspitosa, L.	*Festuca elatior*, L.
**Holcus lanatus*, L.	**Festuca pratensis*, Huds.
**Avena flavescens*, L.	*Festuca loliacea*, Huds.
**Arrhenatherum avenaceum*, Beauv.	*Bromus racemosus*, L.
Phragmites communis, Trin.	**Bromus mollis*, L.
**Cynosurus cristatus*, L.	**Lolium perenne*, L.

Another list is given, numbering twenty-five species, of grasses growing in the same locality, but never appearing upon the water-meadows. The cause of their absence is discussed; the behaviour of two of them, *Catabrosa aquatica*, Beauv., and *Dactylis glomerata*, L., is found difficult to explain.

The *Gramineæ* of the water-meadows are next contrasted with those occurring upon very old non-irrigated grass land in Rothamsted Park, Hertfordshire ('Phil. Trans.,' Part IV., 1882), where twenty species have been recorded. Thirteen species, present both on the water-meadows and in Rothamsted Park, are distinguished by means of asterisks in the above list. Three Rothamsted species, *Avena pubescens*, Huds., *Dactylis glomerata*, and *Festuca ovina*, L., are not found upon the water-meadows. Seven water-meadow species do not occur at Rothamsted, viz., *Phalaris arundinacea*, *Alopecurus geniculatus*, *Agrostis alba*, *Phragmites communis*, *Glyceria fluitans*, *G. aquatica*, and *Bromus racemosus*.

The struggle for existence amongst the water-meadow grasses is discussed, and various morphological and physiological peculiarities of different species are noticed, particularly in their relation to this struggle. The local distribution of certain species, even within the limits of the meadows, is also mentioned.

Three species, *Lolium perenne*, *Festuca pratensis*, and *Glycera fluitans*, exhibit numerous variations, which are described.

The hay crop is probably of far more constant botanical composition than that of ordinary meadows, whereon it differs markedly ('Phil. Trans.,' Part I., 1880) with the character of the season. On the water-meadows the effect of seasonal variations in rainfall is largely eliminated, so that temperature and the duration of sunlight become the dominating factors. Assuming that, in accordance with the researches of Boussingault, Gilbert, Risler, and Hervé-Mangon, it requires a certain total amount of heat above an ascertainable minimum temperature to ripen the seed of any given plant, this amount will be the earlier acquired the hotter the season, and certain species will benefit to the extent that more of their seed will fall to the ground, and so they gain an advantage in the struggle.

Agriculturally *Bromus* and *Holcus* are the most objectionable of the water-meadow grasses. The former, being annual, might be reduced in quantity by early mowing year after year; this, however, might only serve to stimulate the vegetative growth of the latter.

11. Juncus Alpinus, Vill., *as new to Britain.* *By* Charles Bailey.

The author reported to the Section the discovery of this plant at Blair Athole, in Perthshire, by Dr. F. Buchanan White, of Perth, who had sent an example for exhibition to the Section.

12. *Studies on some New Micro-organisms obtained from Air.* *By* Mrs. Percy Frankland *and* Percy F. Frankland, *Ph.D., B.Sc. (Lond.), F.C.S., F.I.C., Assoc. Royal School of Mines.*

In some papers on the micro-organisms present in air, previously communicated to the Royal Society by one of us, the relative abundance of microbes in the air of

different places has been called attention to, and the methods of experiment fully described. As these investigations were carried out with the aid of solid nourishing media, we were able to obtain a collection of pure cultivations of a number of micro-organisms derived directly from the air. It is not unnatural that the brilliant discoveries in connection with the etiology of infectious diseases should have absorbed the lion's share of the attention of investigators in the field of bacteriology, and that the non-pathogenic organisms should have come to be regarded as comparatively uninteresting by the side of their more formidable brethren. But the conversion of sugar into alcohol, the decomposition of nitrogenous organic matter with elimination of ammonia, the oxidation of ammonia to nitrous and nitric acids, besides many other natural transformations which are effected through the agency of such micro-organisms, are certainly not second in importance to the results, terrible as they often are, achieved by the pathogenic forms. The organisms producing the above-mentioned changes are known to be present in the air, and there can be little doubt that the numerous other aërial varieties will in the future be found to discharge important duties in the laboratory of Nature.

We have provisionally given names to the various forms, by which we have endeavoured to indicate some striking peculiarity which the organisms present when examined either in their cultivations or under the microscope.

(1) *Micrococcus carnicolor.*—This is a micrococcus which, when microscopically examined under a high power ($\times$ 1000), is seen to consist of almost round cocci, varying in size from $\cdot 5\,\mu$ to about $1\cdot 5\,\mu$. The larger forms almost invariably exhibit a division. It produces on gelatine-peptone a flesh-coloured expansion, and only liquefies the gelatine in very old cultivations. On agar-agar it grows rapidly, producing the same characteristic shining flesh-coloured expansion. In broth the liquid is clear, free from pellicle, and has a pinkish deposit at the bottom of the tube. When plate-cultivated, the colonies to which it gives rise are seen to be of a faint pink colour. Under the microscope those in the depth are almost perfectly circular and smooth-edged, whilst on the surface they form a thin, almost colourless expansion, which, later, acquires the characteristic pink tint.

(2) *Micrococcus albus.*—This is seen under a high power to consist of cocci varying in size from $\cdot 8\,\mu$ to $1\cdot 5\,\mu$, the larger ones presenting a division. On gelatine-peptone it produces a white shining expansion, with a lobular and smooth edge. It does not liquefy the gelatine. On agar-agar it forms a faintly white, almost colourless, surface-expansion. In broth it renders it very slightly turbid, produces no pellicle, and forms a yellowish-white deposit. The colonies look like small milk-white discs, and under the microscope appear circular and with a sharp edge.

(3) *Streptococcus liquefaciens.*—This is a small micrococcus, varying in size from $\cdot 5\,\mu$ to $\cdot 8\,\mu$, which hang together in short chains. It liquefies the gelatine slowly, producing a light lemon-yellow deposit. On agar-agar it grows slowly, producing an almost colourless shining expansion. In broth it produces a dirty yellowish-white deposit, the liquid remaining clear and free from pellicle. The colonies appear as yellowish pin-heads on the surface, each being surrounded by a slight depression. Under the microscope they are seen to be not always circular, but the edge is smooth.

(4) *Sarcina lutea.*—Under a high power there are seen large cocci mostly grouped together in cubical packets of four or more. It is best seen when lightly stained with methylene-blue. On gelatine it produces a strong lemon-yellow pigment, and causes very slow liquefaction of the medium. On agar-agar this characteristic lemon-yellow pigment is again produced. In broth the liquid is clear and free from pellicle, but it has formed a lemon-yellow deposit. The colonies appear as small yellow centres, whilst under the microscope they are seen to be irregular in shape with a nearly smooth edge.

(5) *Sarcina aurantiaca.*—The packets which this organism forms are seen to be much smaller than those of *Sarcina lutea.* It liquefies the gelatine and forms a flocculent orange deposit. On agar-agar it grows rapidly, producing a strong orange pigment. In broth it renders the liquid turbid and forms an orange deposit. The colonies appear as small, round, yellow dots, which exhibit a circular depression. Under the microscope they are seen to be circular, with a slightly denticulated edge.

(6) *Sarcina liquefaciens.*—Under a high power it much resembles *Sarcina lutea.* It liquefies the gelatine, however, much more rapidly, whilst on agar-agar its growth is very rapid, producing an almost colourless (very faintly green) expansion. In broth the liquid is clear, free from pellicle, with a deposit which later becomes of an orange colour. The colonies appear very faintly green, and form slowly a surface-depression. Under the microscope they are highly irregular in contour, with a denticulated and lobular edge.

(7) *Micrococcus gigas.*—This is seen to be a large micrococcus, sometimes as much as $1{\cdot}7\,\mu$ in diameter: they are frequently adherent in pairs. It liquefies the gelatine slowly, rendering it turbid. On agar-agar it forms a cream-yellow expansion. In broth it produces a whitish deposit, the liquid being clear and free from pellicle. The colonies appear as pin-heads of a faint cream colour, which cause a depression in the gelatine. Under the microscope they are seen to be circular in shape, with a slightly irregular edge and a cloudy centre.

(8) *Micrococcus chryseus.*—This is a micrococcus varying in size, going up to $1\,\mu$ in diameter. The largest cells exhibit a division. It liquefies the gelatine slowly, the depression being filled with semi-liquid cream-coloured matter. On agar-agar it forms a shining expansion of a light orange colour. In broth it produces a dirty white deposit, the liquid remaining clear and free from pellicle. The colonies appear as pin-heads of a yellowish colour. Under the microscope they are seen to be generally round, the more developed colonies showing a finely granular edge.

(1) *Bacillus aurescens.*—This is seen under a high power to be a short bacillus occurring singly, in pairs, and in threads of three and four. The individual bacilli are from three to five times as long as broad, with rounded ends. In drop-cultivations they exhibit vigorous vibratory and rotatory motion, but no movement of translation was observed. When grown on gelatine it forms a light orange-coloured, dry, and much crumpled expansion. It does not liquefy the gelatine. On agar-agar it forms also a dry, light-orange surface-growth. In broth the liquid is clear; there is a deposit of cream-yellow matter, and the surface is covered with a delicate cream-yellow pellicle. The colonies appear as pin-heads of a faint orange colour. Under the microscope they are seen to be not perfectly circular, and have a very slightly jagged edge.

(2) *Bacillus aureus.*—With a high power this is seen to be a bacillus forming fine graceful threads, which are considerably longer than those formed by *Bacillus aurescens.* In drop-cultivations they exhibit only vibratory motion. On gelatine it forms a dry crumpled expansion, which is of a much deeper orange colour than *B. aurescens.* In old cultivations slight liquefaction of the gelatine takes place. On agar-agar it forms an orange growth, which is less crumpled and less dry in appearance, but deeper in colour than that of *B. aurescens.* In broth it resembles *B. aurescens,* but the deposit and pellicle are deeper in colour. The colonies differ little from *B. aurescens,* except that they are deeper in colour and more rapid in their growth.

(3) *Bacillus citreus.*—This is seen under a high power to be a short fat bacillus, about one-and-a-half to twice as long as broad. Sometimes they hang together in chains of three and four. The average length of a pair is about $3{\cdot}4\,\mu$; the ends are rounded and sometimes pointed, especially in those cases where division has taken place. Often it assumes forms of peculiar shape, some of the bacilli being bent and often club-shaped. It is non-motile. On gelatine it grows slowly, producing shining and smooth lemon-yellow expansion. On agar-agar it forms a moist, shining, sulphur-yellow expansion. When grown in broth the liquid remains clear, free from pellicle, and forms a slight yellowish deposit at the bottom. The colonies appear as dots of a strong yellow colour. Under the microscope they are more or less circular in shape, with an almost smooth edge.

(4) *Bacillus plicatus.*—Under a high power this is seen to be a very minute bacillus about $1\frac{1}{2}$ times as long as broad. It forms short threads, and is very motile. No spore-formation was observed. It forms a much crumpled and folded greyish expansion, the surface of which is abundantly pitted and excavated. No liquefaction of the gelatine takes place. On agar-agar it grows very similarly, only

the expansion is rather more moist. In broth it renders the liquid very slightly turbid, causing a dirty white deposit, and forms on the surface a tough, irregular pellicle. The larger colonies, which are on the surface, exhibit an indentation in the centre; as growth proceeds the centre remains depressed, whilst the edge becomes irregularly folded and raised, until at length the colony is only attached to the gelatine by a comparatively narrow portion of the growth. The substance of the colony is very tough in character. Under the microscope the small colonies have a rough, irregular edge, and vary in shape and degree of roundness. The larger colonies are very irregular in shape.

(5) *Bacillus chlorinus.*—This is seen to be a very short bacillus, varying from $\cdot 5\,\mu$ to $1\cdot 5\,\mu$ in length, and about half as broad as long; the ends are rounded. It occurs singly and in short chains. Only vibratory motion was observed. It liquefies gelatine slowly, producing a lemon-yellow deposit. On agar-agar it produces a strong, almost uniform, shining surface-growth of a greenish-yellow colour. In broth it renders the liquid slightly turbid, and produces a dirty-yellow deposit; no pellicle is formed. The colonies form shining greenish expansions. Under the microscope they are seen to have a thin, smooth edge, with very fine granular contents.

(6) *Bacillus polymorphus.*—This organism exhibits a great variety of forms, even in cultivations only one day old. Small fat bacilli, almost like micrococci, are found; then there are longer forms, frequently occurring in pairs and also forming strings of irregular thickness. These strings show frequently no signs of division, and sometimes reach $1\cdot 7\,\mu$ in length. The isolated bacilli are $\cdot 8\,\mu$ in length and nearly as wide. All these various forms were obtained from one and the same colony. Vibratory motion only was observed. On gelatine it grows slowly, producing an expansion regular in its shape and minutely serrated at the edge. The surface of the growth is white, but as the cultivation gets older the centre becomes tinted slightly yellow. No liquefaction takes place. On agar-agar it grows also with a highly serrated edge. In broth it forms a white deposit and produces a thin cloudy-white pellicle on the surface. The colonies are circular and bluish-white, with a small yellow spot in the centre. On the surface they form pin-heads. Under the microscope the surface colonies are seen to be circular, with an irregularly corrugated edge. The central portion is cloudy and surrounded by a distinct ring. The smaller colonies in the depth are very irregular in shape and resemble the corolla of a flower.

(7) *Bacillus profusus.*—This is seen to be a short fat bacillus with rounded ends. The length reaches about $1\cdot 7\,\mu$ and the width about $\cdot 5\,\mu$, but its dimensions are very variable. They only exhibit vibratory motion. On gelatine it spreads over the surface in a thin layer, which has a beautiful opalescent appearance when viewed by transmitted light. On agar-agar it forms a much thicker growth, forming a smooth whitish lobular expansion. In broth it forms a whitish deposit, whilst on the surface it produces thin granular floating matter. The colonies form an opalescent expansion on the surface, with a very irregular contour. Under the microscope the surface colonies exhibit a dense centre surrounded by a very thin granular expansion having a highly irregular contour. Against the light these surface colonies are of a beautiful azure-blue colour.

(8) *Bacillus pestifer.*—This is seen to be a large thick bacillus about $3\cdot 4\,\mu$ in length and from $\cdot 8\,\mu$ to $1\cdot 7\,\mu$ in thickness. It forms threads sometimes of great length, which give rise to winding vermiform figures. Their movement is slow and undulating, the single bacilli exhibiting most motility. No spore-formation was observed. In gelatine it produces an almost colourless feathery expansion, which causes slow liquefaction of the medium. On agar-agar it forms a moist and shining grey-white expansion, which sometimes becomes very much wrinkled. In broth the liquid is turbid, free from pellicle. A small quantity of white deposit is formed. The colonies appear as white specks only to the naked eye, but under the microscope they are seen to be very irregular in contour, consisting of threads branching into the surrounding gelatine; later the centre becomes very dark and cloudy, but the edge remains light. Later these feathery contours can be seen with an ordinary magnifying glass. In all cultivations this organism gives rise to a most disagreeable odour, somewhat resembling that of putrid blood.

(9) *Bacillus lævis.*—This is seen to be a bacillus whose average length is 1·7 to 2·5 μ, and is about five times as long as broad: the ends are distinctly rounded. It occurs singly, in pairs, and occasionally in threads. It forms spores nearly as long as the bacillus itself. It exhibited all the well-known forms of *Bacillus subtilis*, but on a much smaller scale. It is very motile. It liquefies the gelatine, rendering it turbid, producing a flocculent deposit and forming a tough, greyish, wrinkled pellicle on the surface. On agar-agar it forms a moist, shining, greyish-white surface-expansion, which grows quickly over the whole agar-agar. It renders the broth at first turbid, but it subsequently becomes clear, a thin, granular pellicle forms on the surface, and there is a dirty-white flocculent deposit. The colonies appear as small white dots, which subsequently liquefy the gelatine. Under the microscope the depth colonies have a smooth edge which is irregular in shape. Those on the surface exhibit a very fine thin film, of irregular shape, extending from a small centre.

(10) *Bacillus cereus.*—The individual bacilli are from 3·4 μ to 12 μ in length; it also presents thickened forms about 3·4 μ long and 1·7 μ wide. The ends of the bacillus are generally slightly rounded, whilst some are quite square. It forms threads which are very variable in length. It also produces spores and is motile. It liquefies the gelatine very rapidly and forms a pellicle on the surface, and produces a flocculent deposit. On agar-agar it forms a smooth, grey-white, wax-like expansion. It renders the broth turbid, and forms a pellicle on the surface. The colonies are very characteristic. When small (under the microscope) they appear as round or oval woolly masses with a finely spinose edge, from which, in many cases, long whip-like and spirally-coiled threads extend into the surrounding gelatine. Sometimes on reaching the surface they give rise to highly irregular filamentous growths consisting of bands of fine thread. Subsequently the whole plate becomes liquefied.

(11) *Bacillus subtilis.*—Under a high power the individual bacilli are seen to vary in length from 1·7 μ to 6·8 μ, whilst in width they are about 1·7 μ; the ends are slightly rounded, but sometimes nearly rectangular. Prior to spore-formation the bacilli become thicker and more square. It forms threads which are frequently of great length. It is very motile. It liquefies the gelatine, forming a tough white pellicle on the surface. On agar-agar it rapidly grows over the surface, forming a white opaque expansion, which soon becomes dry and copiously wrinkled. In broth it renders the liquid turbid, giving rise to a white deposit, and forming a pellicle on the surface. It produces colonies of very characteristic appearance, of which only the finely spinose edge colonies have been previously described. In addition it forms what may be called *whip-colonies*, from the curiously twisted threads, like the lash of a whip, which grow out from a compact centre. Another variety are the *meander-colonies*, which consist of parallel bands of threads meandering in the most capricious manner over the surface of the gelatine. Subsequently the whole plate becomes liquefied.

SATURDAY, SEPTEMBER 3.

The following Papers were read:—

1. *Recent Researches on Earthworms.* *By* W. B. BENHAM, *D.Sc.*

I. The genera (other than Lumbricus) formed before Perrier's work in 1872 must be, in most cases discarded, as only external features were noted. Only Hoffmeister's *Criodrilus* and Schmarda's *Perichæta* are now retained.

II. Perrier described and figured the external and internal anatomy of eleven genera: *Anteus, Titanus, Rhinodrilus, Eudrilus, Perionyx, Digaster, Moniligaster, Urochæta, Pontodrilus, Plutellus, Acanthodrilus.* But his arrangement of these into Preclitelliani, Intraclitelliani, Postclitelliani, Aclitelliani is now seen to be unnatural.

III. More recent authors, and the genera formed by them—Beddard: *Typhæus, Thamnodrilus, Microchæta.* Benham: *Diachæta, Urobenus, Trigaster.* Fletcher: *Didymogaster, Cryptodrilus, Notoscolex.* Various other observations by these, and by Bourne, Eisen, Horst, and Rosa, &c.

IV. Geographical distribution of these genera.

V. Description of primitive earthworm, with—

a. Complete circle of setæ.
b. Numerous nephridia.
c. Short clitellum.
d. Single pair of testes, seminal reservoirs, ovaries, &c.
e. Nephridia modified as genital ducts.
f. Gizzard and typhlosole and intestinal glands.

VI. Arguments in favour of the above statements, drawn from—

a. Arrangement of setæ in Perichæta, Diachæta, Urochæta, penial setæ of Acanthodrilus, scattered setæ of many species.
b. Numerous nephridia of Perichætæ, and nephridia of *A. multiporus.* Alternation of nephridia in Plutellus. Lankester's theory supported.
c. Short clitellum of many existing worms and in river worms.
d. Genital system in Urochæta, Diachæta, &c., with one pair testes, &c. Increased production of spermatozoa necessitates increased means of removal. Manner of modification of nephridia, as sperm-ducts and spermathecæ.

VII. Comparative morphology considered very briefly. Form, clitellum, setæ, position of malepore. Genital system in—

1. Lumbricidæ, &c.
2. Perichætidæ, &c.
3. Titanus, &c.
4. Eudrilus.
5. Moniligaster.

Alimentary system—degeneration of Pontodrilus and Criodrilus.
Vascular system—double dorsal vessel in Acanthodrilus sp., Microchæta, and young Criodrilus.

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2. *The Problem of the Hop-plant Louse* (Phorodon humuli, SCHRANK) *in Europe and America.* *By* C. V. RILEY, *M.A., Ph.D.*

The author has been for several years carrying on investigations with a view of ascertaining the full annual life-history of *Phorodon humuli*, and especially with a view of settling the hitherto mooted question as to its winter life. The importance of the inquiry, both from the economic and the scientific sides, is self-evident. The hop crop, in all parts of Europe where it is grown, and especially in England, annually suffers more or less from the ravages of this its worst insect enemy, and in some years is a total failure. The same is true in North America, at least east of the Rocky Mountains, and last year the injuries of this Phorodon in the hop-growing regions of the State of New York were so great that many hop-yards were abandoned and have since been ploughed up; while but 10 per cent. of an average crop was harvested. From the purely scientific side, entomologists, notwithstanding the great interest attaching to the subject, have been divided in opinion as to the identity, or specific relationship, of the hop Phorodon and one that occurs on Prunus, while the complete annual cycle of the insect's life has remained a mystery. After full and satisfactory investigations the writer has satisfied himself that, contrary to the prevailing impression among hop-growers and previous investigators, the Hop-

plant Louse does not hibernate underground on the roots of the hop; nor in, on, or about anything in the hop-yard; but that, upon the advent of the first severe frosts, the hop-plant and the hop-yards are entirely cleared of the species in any form. I find that all statements to the contrary in America are based on misapprehension, or mistaken identity of species, and I believe (though admitting the possibility of variation in this respect in milder climates) that the same will be found to hold true in England, where hibernation on the hop-root has been accepted by high authority. The positive statements made about eggs being laid in autumn, whether on roots or upon the bines left in cutting, or which are carted away, are based on conjecture, and have been blindly copied without credit by one writer from another, a practice too common among secondhand writers on economic entomology.

The conjectures of some of the best students of Aphidology that *Phorodon humuli* had a form (*mahaleb,* Fonsc.) living on Prunus, and that there was a consequent migration from one plant to the other, I have positively proved to be correct, by direct colonising from Prunus to Humulus, and by continuous rearing from the original stem-mother hatched from the winter egg.

The observations have been made on growing plants and in vivaria at Washington, and checked by others made simultaneously in hop-yards at Richfield Springs, N.Y. An incident may here be recorded as illustrating the effect of meteorological extremes upon aphides. The extreme heat (over 100° F.) and dryness of July 17th and 18th killed every one of the insects under observation at Washington, entirely clearing the plants. The economic bearing of such exceptional phenomena, as also of the biologic observations made, is readily understood.

The more important conclusions from the studies so far made are thus summed up in a paper which I had the honour to read before the American Association at its recent meeting in New York:—

1. *Phorodon humuli* hibernates in the winter-egg state, this egg being fastened to the twigs (generally the previous year's growth) of different varieties and species of Prunus, both wild and cultivated. The egg is ovoid and 0·04 mm. long, green when first laid, but polished black subsequently.

2. The annual life-cycle is begun upon Prunus by the stem-mother, which hatches from this winter-egg. This stem-mother is stouter than the individuals of any of the other generations, with the legs, antennæ, and honey-tubes relatively shorter, while the cornicles between the antennæ are sub-obsolete. The colour is uniform pale green, with bright red eyes and faintly dusky tarsi.

3. Three parthenogenetic generations are produced upon Prunus, the second at once distinguished by its more elongate form, much longer members, distinct cornicles, and markings of darker green; while the third (or typical *mahaleb* form) becomes winged, and instinctively abandons the Plum and migrates to Humulus. The habit of moving from plant to plant after giving birth to an individual, and thus scattering the germs of infection on Humulus, is well marked in this winged generation.

4. During the development of the three plum-feeding generations, the Hop is always free and, subsequently, until the return migration, the Plum becomes more or less fully free from infection by this species.

5. A number of parthenogenetic wingless generations are produced on the Hop (seven, or the tenth from the stem-mother on Plum having been traced up to August 5th, and advices of the eleventh up to August 19th having been received since my arrival in England); and, finally, there is a return migration of winged females to the Plum in autumn. The wingless Hop generations are not only incapable of migrating to Plum, but do not thrive upon it when artificially transferred thereto.

6. Exact observations are not yet complete as to the full number of generations produced upon the Hop before the winged return migrant appears, and another month's careful watching and experiment is needed to fill this hiatus in the annual cycle, as also to ascertain the exact number of generations produced in autumn on the Plum. From knowledge extant and previous general observation, the facts will probably prove to be as follows:—

7. The eleventh or twelfth generation will produce winged females (from the middle to the end of August), which will deposit their young upon the Plum; and these will become the only sexed individuals of the year—the male winged and the female wingless, the latter after coition consigning a few impregnated or winter-eggs to the twigs.

8. At the date of writing (August 5th) the first females on Hop were still alive and breeding, having existed two months. There is, consequently, an increasing admixture of generations from the first on Hop until frost overtakes the species in all conditions and sweeps from the hop-yards all individuals alike, perpetuating in the egg state those only which reach the sexual condition on the Plum.

9. Each parthenogenetic female is capable of producing on an average one hundred young (the stem-mother probably being more prolific) at the rate of one to six, or an average of three per day, under favourable conditions. Each generation begins to breed about the eighth day after birth, so that the issue from a single individual easily runs up, in the course of the summer, to trillions. The number of leaves (700 hills, each with two poles and two vines) to an acre of Hops, as grown in the United States, will not, on the average, much exceed a million before the period of blooming or burring; so that the issue from a single stem-mother may, under favouring circumstances, blight hundreds of acres in the course of two or three months.

10. While meteorological conditions may materially affect the increase and power for injury of the species, these are far more truly predetermined and influenced by its natural enemies, many of which have been studied and will be described.

11. The slight colorational differences, as also the structural differences, including the variation in the cornicles on head and basal joints of antennæ, whether upon Plum or Hop, are peculiarities of brood, and have no specific importance whatever.

12. The exact knowledge thus gained simplifies the protection of the Hop-plant from Phorodon attack. Preventive measures should consist in destroying the insect on Plum in early spring where the cultivation of this fruit is desired, and the extermination of the wild trees in the woods wherever the Hop interest is paramount; also in avoiding the introduction of the pest into new Hop countries in the egg state upon plum cuttings or scions. Direct treatment is simplified by the fact that the careful grower is independent of slovenly neighbours, infection from one hop-yard to another not taking place.

Experiments still under way have shown that there are many effective remedies, and that the ordinary kerosene emulsion diluted with 25 parts of water and sprayed with the cyclone nozzle; or a soap made by boiling 1 lb. of pure potash in 3 pints of fish oil and 3 gallons of water, and this dissolved in 8 gallons of water, and sprayed in the same way—are thoroughly effectual remedies, and leave the plant uninjured. The former costs 75 cents, the latter 30 cents, per acre, plus the time of two men for three hours, plus appliances. The object of further experimentation now being carried on is to simplify and reduce the cost of these last to a minimum. As they consist, however, essentially of a portable tank and a force pump with hose and spraying attachment which, together, need not involve a greater first outlay than $5 to $10, and as every American Hop-grower can afford to expend the larger sum for the protection of a single acre, there is no longer any excuse for allowing this pest to get the better of us.

It is not my purpose, however, to enter into aphidicide details in this communication, which I will conclude by brief reference to the bearings of these discoveries in America on the problem in Great Britain. The most comprehensive and satisfactory review of the knowledge possessed on the subject in England that has come to my notice, is that by my esteemed friend and correspondent, Miss Eleanor A. Ormerod, consulting entomologist of your Royal Agricultural Society, in her 'Report of Observations of Injurious Insects,' &c., made in 1885. So far as her own careful observations are concerned they fully accord with the facts here set forth; but on the authority of others, and especially on the evidence of Mr. C. Whitehead, who reported finding young lice and large viviparous females on

Hop-shoots as early as March 29, and that of Mr. A. Ward, who experimented with surface dressings near Hereford, Miss Ormerod concludes that attack on the Hop begins in spring from wingless females which come up from the Hop hills; and as a corollary, that dressings to prevent such ascent are strongly to be recommended. It is quite within the range of possibility, and what is known of aphid life, that where the winters are mild, with scarcely any frost, this Phorodon may continue on the Hop from one year to another in the parthenogenetic condition. If such is ever the case in England you have a somewhat different set of facts to deal with here from what we have in America. But for the reasons already stated in abstract, from many other detailed observations which it would be tedious to record here, as well as from the ease with which erroneous conclusions are arrived at, where not checked and proved by the most competent and careful study, I shall be inclined to believe that the facts in England are essentially the same as I have found them in America, until convincing and trustworthy evidence to the contrary be forthcoming. Mr. Whitehead may have had another species under observation, and Mr. Ward's surface dressings may have acted by repelling the winged female migrating from Prunus, in the same way that buckwheat sown among the Hops is believed to do with us.

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3. *Arteries of the Base of the Brain.* *By* Bertram C. A. Windle, *M.A., M.D. (Dublin), Professor of Anatomy in the Queen's College, Birmingham.*

The abnormalities of the basal arteries of the brain have not to my knowledge been hitherto described from any extended observations. I have notes of two hundred cases, of which the following paper is a summary:—

Anterior Communicating Artery.

Double	14
Triple	1
Union and subsequent division of anterior cerebrals	6
" " " " together with a communicating	2
None from union of two anterior cerebral arteries	1
" absence of one anterior cerebral artery	2
A second communicating running into first	6
A median artery derived from communicating	9
Normal	159

Anterior Cerebral Arteries.

A third or median from anterior communicating	9
None on R., but twig from left middle cerebral	1
" " " internal carotid	1
Complete union of two arteries	1
Normal	188

Posterior Cerebral Arteries.

From carotid on R.	11
" " L.	9
" " both sides	4
Two on L. side, one from basilar, one from carotid, with slight anastomosis	1
Normal	175

Posterior Communicating Arteries.

None on R	9
" L	13
" either	3

Posterior Communicating Arteries—continued.

Right greater than left	28
Left " right	15
Both very small	7
Normal	125

Arterial system completely normal in 76. The only abnormality in 43 was difference in size between the two posterior cerebral arteries.

4. *On Alteration of Iliac Divarication and other Changes of Pelvic Forms during Growth.* *By* Professor CLELAND, *F.R.S.*

It was pointed out that the iliac divarication diminishes from childhood to early adult life, and after adult life is reached it tends again to increase. The diminution was traced to the widening of the sacrum on each side opposite the lower end of the auricular surface; the later increase of the divarication is owing to muscular action, and is greatest in heavily built elderly persons.

The conjugate and transverse diameters of the pelvis are found by the author to be about equal in young children, while afterwards the conjugate diameter grows more rapidly than the transverse, till about twelve or thirteen years of age, after which the adult form is approached by the method pointed out by Dr. Matthews Duncan.

5. *The Brain Mechanism of Smell.* *By* Dr. ALEX. HILL.

6. *The Nature and Development of the Carotid System.* By JOHN YULE MACKAY, *M.D.*

The study of the comparative anatomy of the carotid arteries brings to light a series of facts which suggest a theory of development different from that at present accepted. In the mammalia the common carotid artery divides after a longer or shorter course into an internal and external branch, the former supplying the brain, the latter the rest of the head. The common carotid is regarded as the portion of the truncus arteriosus stretching between the ventral ends of the third and fourth fœtal branchial arterial arches, its external branch as the continuation of this towards the head, and the internal carotid as the third arch and its dorsal prolongation to the head. The portion of the continuous dorsal vessel between the third arch and the aorta, or fourth arch, has in the mammalia disappeared in the course of development. The external carotid artery is thus regarded as a ventral, the internal carotid as a dorsal, vessel. Notwithstanding that in no other vertebrate group than mammals are the external carotid branches gathered together into one stem distinct from the internal carotid artery, the same scheme of development has been applied to the explanation of the details in the other classes, the artery supplying the brain being looked upon as the sole dorsal trunk, and all the other arteries of the head as ventral.

In the fish the blood-vessels which supply the head externally and internally do not take their origin until the blood has become arterialised after its passage through the gills, and spring consequently from a dorsal trunk. In the amphibian, however, two vessels pass forwards from the third arch, one upon the ventral and the other upon the dorsal aspect of the alimentary canal. The ventral vessel is small and extends no farther forwards than the tongue, while, on the other hand, the dorsal artery is large and supplies the whole of the head, its branches in the frog being named, according to Ecker,[1] 'ascending pharyngeal,' 'ophthalmic,' 'palatine,' and 'internal carotid.' This dorsal artery is in the young amphibian in direct continuity with the aorta, but in the adult that portion of the dorsal vessel between the third and fourth arches is often reduced to a solid cord.

In the lacertilian the arrangement of the carotid vessels is similar to that in the amphibian. The ventral vessel supplies the under surface of the neck and the tongue, and one branch reaches as far outwards as the shoulder, and comes into

[1] *Anat. des Frosches.* Braunschweig, 1864.

anastomosis there with branches of the subclavian artery. This branch is of greater size and importance in other reptilian forms and in birds. The dorsal vessel supplies the whole of the head, its branches are numerous, and a number of those which supply the outer aspect are grouped together at their origin into one trunk. This dorsal vessel is in most cases continued directly backwards into the aorta as in the young amphibian.

The carotid arteries of the chelonian when examined closely are found to resemble in position and distribution the vessels described in the lacertilian. A ventral vessel extending to the tongue, but not constituting the whole supply of that organ, runs forward upon the under surface of the throat. This ventral vessel is a branch of the subclavian, but the apparent anomaly of its origin is explained by the fact that the subclavian of the chelonian does not correspond to the subclavian of the lacertilian, but to that branch of the ventral carotid which has been already described as passing outwards to the muscles of the shoulder. The dorsal artery of the chelonian is similar in all its more important characteristics to that of the lacertilian, and supplies the head externally and internally.

The arrangement of the vessels of the crocodile resembles that of the chelonian. The ventral vessel 'arteria collateratis colli' arises with the subclavian, and runs forwards to the tongue. The dorsal artery supplies the whole head and partly also the tongue. This dorsal vessel may, upon each side in young specimens of Crocodilus Niloticus, be seen to be continued back to the aorta by a solid cord, and it is therefore obviously identical with the dorsal artery of amphibia and lacertilia.

The arterial system of the bird resembles closely that of the crocodile. The ventral vessel, however, is very small, and, taking origin from the base of the subclavian, does not reach so far forward as the tongue. The dorsal vessel supplies the tongue and the whole of the head, and is usually called 'common carotid artery.' It is sometimes to be found connected with the aorta by a solid cord as in the other groups.

As in all the groups less advanced than mammals the branches to the external aspects of the skull are dorsal in origin, it is probable that the external carotid artery of mammals ought also to be regarded as developed from a dorsal trunk. In all the different classes the branches of the dorsal carotid trunk are freely connected by longitudinal anastomosing chains with those of the dorsal aorta. In the frog the occipital artery is prolonged from the subclavian to anastomose with branches of the dorsal carotid upon the skull. In the lacertilia an inferior thyroid artery anastomoses with a branch of the carotid passing backwards. In chelonia an occipital and a deep cervical artery form an anastomosis, while in birds and crocodiles the vertebral artery marks an anastomotic chain. In the mammal these three chains are all present as a rule, and two of them pass between the external carotid and subclavian arteries. It is probable, therefore, that the branches of the external carotid of the mammal are to be compared to those of the dorsal carotid of other forms. The ventral carotid vessel in the lower forms passing as far forwards as the tongue, but almost entirely continued into the subclavian in crocodilia and aves, would seem to be represented in the mammal by the thyroidea ima artery, a vessel rare in the human subject but constant in the cetaceæ.

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7. *The Development of the Supra-renal Capsules in Man. By* Dr. C. S. Minot.

MONDAY, SEPTEMBER 5.

The following Papers were read :—

1. *Discussion on 'Are Acquired Characters Hereditary?' in which* Professor Lankester, Professor Weismann, Professor Hubrecht, Patrick Geddes, M. Hartog, *and* E. B. Poulton *took part.*

2. *Further Experiments upon the Colour-relation between Phytophagous Larvæ and their Surroundings.* *By* E. B. POULTON.

From the instance of the larval *Smerinthus ocellatus* I have shown that certain lepidopterous larvæ are susceptible to the influence of surrounding colours, so that the larvæ themselves gain a corresponding appearance.[1] This larva varies from bright yellowish green to a dull whitish or bluish green, and either variety can be produced by the use of a food-plant with the appropriate colour on the undersides of the leaves. Although the difference between the two varieties is very great when they are placed together—so great in fact that I can readily distinguish three intermediate stages of variation between the extremes—yet it is not nearly so well marked as in the case of the green and brown varieties of many dimorphic larvæ. I was therefore anxious to test one of these latter, and to ascertain whether either variety can be produced at will by surrounding the larva with the appropriate colour. Lord Walsingham had previously called my attention to the variable larvæ of *Rumia cratægata*, some of which are brown, some green, while many are intermediate. The larva exactly resembles the twigs of its food-plant, and always rests upon the branches in a twiglike attitude; and this habit rendered the species very favourable for the purpose of this inquiry, which was conducted as follows. A glass cylinder was provided with a black paper roof, a similar floor, and a small quantity of the food-plant (hawthorn), the rest of the space being entirely filled with dark twigs. Owing to their habit the larvæ always rested upon these latter, and after reaching maturity in two such cylinders forty dark varieties were produced. Three other cylinders were roofed and floored with green paper, and green shoots bearing leaves were introduced as food, nothing brown being allowed inside the cylinders. In these cylinders twenty-eight green varieties were produced. The young larvæ were obtained from the eggs of three captured females. After hatching, the larvæ were thoroughly mixed, and introduced into the cylinders when quite small. Some of the dark varieties were greenish and some of the green larvæ brownish; but the greenest in the dark cylinders was browner than the brownest in the green cylinders. The larvæ were compared by placing the sets side by side upon white paper, and the contrast between the larvæ brought up in different surroundings was very marked. In this case the larvæ ate precisely the same kind of leaf, so that it is clear that the effects follow from the surrounding colours, and not from the action of food. The instance recorded above is the best among the many cases of adjustable colour-relation which are now known in lepidopterous larvæ. It is now extremely probable that all dimorphic species will show more or less of this susceptibility to the colour of their environment.

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3. *Some Remarks on the Recent Researches of Zacharias and Dr. Boveri upon the Fecundation of the Ascaris Megalocephala.* *By* Professor J. B. CARNOY, *of the University of Louvain.*

The first kinetic polar figure of this ascaris was given in the 'Prospectus' of my 'Biologie Cellulaire' in 1883. Since then I have published three notices on the polar globules and the fecundation of the nematoids. At the end of the first article, which treated of the Ascaris Megalocephala, I expressed a desire to see my remarks commented on by some earnest and disinterested writer. O. Zacharias and Boveri have carried out this desire.

I. *Polar Globules.*

1. The remarks of Zacharias confirm my own on all important points: (*a*) There is neither micropyle nor '*bouchon d'impregnation.*' He admits with me (*vide* 'Prospectus') that the spermatozoid penetrates into the egg *by digesting* its membrane. (*b*) The kinetic figures are opened and divided into two from their very commencement; therefore the ypsiliform figure of van Beneden does not exist. (*c*) The figures of the two globules are identical. (*d*) Out of eight nucleïnic primitive

[1] An account of these experiments will be found in *Proc. Roy. Soc.* No. 237, 1885, p. 269, and No. 243, 1886, p. 135.

elements, four are rejected with the first globule, without undergoing any change; two with the second. Only two therefore remain for the actual nucleus of the egg. At no stage therefore is there any division of the nucleïnic rods, whether longitudinal or transversal, nor any clearing of the nucleïn. On all these points O. Zacharias supports me in opposition to E. van Beneden.

Still we differ on a few details.

(*a*) According to Zacharias, the Wagnerian spot, which is at first single and homogeneous, divides into two parts, which are likewise homogeneous, and in each of which later on chromatic globules appear. We cannot admit these assertions. The nucleus of the young eggs is an ordinary nucleus, and in which the nucleïnic thread gives birth to eight rods, forming two quarternary groups. The apparent homogeneity of the Wagnerian spot is invariably the result of bad treatment in the preparation. As for the presence of globules instead of rods, it is the effect of the reagents or of the position of the rods as seen by the observer; that is quite certain. I have always maintained these various points in whatever I have published. My opponent admits moreover that the two spots are not nucleoles in the sense in which Zacharias takes them (I call them plasmatic nucleoles); but without coming to any decision on their nature, he gives them the name of 'mitoblast.' I had shown that they were ordinary nucleïnic nucleoles—the name 'mitoblasts' is therefore needless, and as such should be rejected.

(*b*) Zacharias did not notice any asters in the first figure. This may have been perhaps from his having only seen our compressed figures, for usually the presence of asters, oftentimes well developed, is unquestionable.

(*c*) According to Zacharias, half the globules of each nuclear group are discharged with the polar globules. When the groups are very close together it is more difficult to come to a decision; but when the figures are well opened or ruptured it is ascertained that one of the groups is discharged and that the other remains in the egg. Moreover, the only essential point is that six of the primitive elements are expelled *in toto*.

2. Boveri admits the existence of two Wagnerian spots, but according to him these consist of a thick single prismatic rod, and are consequently homogeneous.

These rods would undergo a binary division at the equator of each figure, and the halves would withdraw to the poles. The exterior group is then expelled with the globule. We must reject these assertions. The two primitive rods do not exist. They are undoubtedly formed of four distinct rods, which are blended, owing to Boveri's imperfect preparations. His supposed equatorial division is then but an illusion, as the eight rods have always been distinct. As for their motion towards the poles, I have never noticed it in the Ascaris Megalocephala. The first spindle disappears, and Boveri seems in this to be at one with me. The separating spindle is consequently distinct from the first. However, in other species I have studied the polar ascent really takes place, and the separation of the polar globule sometimes occurs in the kinetic spindle itself. It would not at all astonish me to come across these characteristics in some varieties of the Ascaris of the horse. I do not intend to treat of the normal form of the figure: that question was treated, *ex professo*, in the 'appendix' to my lecture given at Brussels on March 5, 1887.

II. *Fecundation.*—Nussbaum contends that the two fusing nuclei always fuse in the centre of the egg. E. van Beneden contends that the fusion never takes place before the figure of segmentation is formed. These two opinions are too absolute. I have shown that this fusion sometimes takes place, sometimes does not. As regards the fact itself, Zacharias and Boveri side with me. The former of these two *savants* seeks to explain this difference. In his opinion, when the figure is formed without previous fusion of the nuclei, the fusion had already taken place at the top of the egg, and the result has been two hermaphrodite nuclei. We do not think that is the case. In fact, his figures, 10 to 13, Plate IX., showing this fusion, have left me in doubt, for I have come across a number of similar figures during my investigations, but the male nucleus, which it is difficult to make out at that stage of its evolution, was still in the centre of the egg; it was therefore not in a fair way of fusing with the female element. The figure of the top of the egg simply represents the female nucleus in which the primitive rods

have separated, either apparently or in reality, into four and sometimes even eight fragments. Could the presence of the male nucleus have by any chance escaped the notice of Zacharias? . . . In all the nematoids I have studied, I have nearly always ascertained the progressive elaboration of the female nucleus, whilst at the same time the male nucleus, which was visible at the various stages, was gradually developing. Then, again, in such species as the *Ascaris clavata*, where the equatorial division takes place, the ultimate nucleus of the egg is completed, as at the end of the ordinary kinesis.

In short, if the first mode exists, viz. the normal mode of Zacharias, it seems to me but to represent a special and, perhaps, an eventual mode of fecundation in the nematoids. Whether the fusion of the male and female nucleus takes place at the top of the egg, or later after their distinct elaboration, or lastly during the kinesis of segmentation, it matters little; at all events the fusion, in my opinion, does take place, and that is the essential point. I must, therefore, on this subject, maintain my former conclusions.

I shall be happy to put at the disposal of my learned colleagues, to whom the matter may be of interest, a number of preparations obtained from various nematoids.

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4. *The Spermatogenesis of the Acarians and the Laws of Spermatogenesis in general. By* Professor GILSON.

This paper is but a very short abstract of a chapter of my work upon the spermatogenesis of the Arthropods, which is still in course of publication. The original paper would have been too long to read in French without exhausting your patience, but on the other hand I must claim your indulgence for this English abstract.

The spermatozoa of this group of Arthropods are not yet very much known.

Leydig and Pagenstecher give only a few drawings and a very short description of them. Claparède and Henking have also studied the spermatozoa of Atax, Tetranychus, and Trombidium. But these are—according to their drawings—thoroughly different from those we have found in the Gamasids and the Ixodids. These bodies show, however, very interesting features in their constitution and genesis.

The multiplication of the mother-cells, which give origin to the spermatic cells, takes place by binary segmentation. The spermatic cell contains a large nucleus, in which a little nucleolus is visible. In this are enclosed the bits of nucleinic substance (or chromatin) perfectly colourable by the methyl-green.

According to the appellation proposed by Professor Carnoy for that kind of productions this nucleolus is to be called in French 'nucléole-noyau,' and could be called in English 'nucleo-nucleolus,' or nucleus-shaped nucleolus.

This cell grows longer into a rather thick spindle. The nucleus takes also a lengthened shape. But the nucleus-shaped nucleolus remains intact in form and in internal structure.

Under the membrane of the cells appear longitudinal or transversal lines, according to the species. Those details depend on the external layer of the protoplasmic reticle which is contiguous to the membrane. In the same time the lengthened true nucleus becomes incrusted with a hyalin substance.

In several species the nucleus-shaped nucleolus pierces the cell's membrane, and remains entangled in the same and externally prominent.

The spermatozoa are free; ordinarily unmoved in the male; animated with light contractions in the female.

Many might consider that the spermatogenesis of those animals I have just shortly described is a deviation from what they would call *the general law of spermatogenesis.* As for me I rather think that there is no general law existing for the spermatogenesis.

The phenomena of the genesis and the differentiation of the spermatic cell are, indeed, extraordinarily diversified—to such a point that, in order to get them together in a single formula, it would be necessary to say: *the development of spermatozoa includes several different processes of cellular genesis and differentiation.*

In order to render this formula more determinate I consider it impossible, in the actual state of science, to add to it any note concerning either the genesis or the differentiation of the spermatic cell, *without restraining its extension.* More specified, it would no more apply to *all the living* forms, and it would cease to be *general,* since nothing is more diversified than the alterations of that genesis and differentiation which were observed in the different degrees of the organic series.

But, such as I have expressed it, this formula, which can apply to every kind of cells, is not the synthesis of the facts observed in spermatogenesis. It is not a biological law, because a biological law is nothing other than the synthesis of the facts. So I may say that there is no general-law existing for spermatogenesis. There are no other general laws than these which regulate the genesis and the differentiation of every kind of cells; laws which still totally evade research, and are dependent on the inmost constitution of organised substance.

But no general law existing, it is evident, however, that after long comparative and conscientious analytic researches, one may make the synthesis of the facts, and look for special laws for the different groups of beings. It would be desirable that this synthetical work were made from a comparative cytological point of view, in order to avoid the false interpretations and the multiplication of useless terms. Let us add that it would be also desirable that, in the synthetical summaries, as well as in the statement of the researches, separate descriptions should be given of the facts belonging to the three periods of spermatogenesis, namely:—

The period of the multiplication of the mother-cells; the period of the differentiation of the spermatic cells; and the period of the different phenomena which follow the completion of the spermatozoon. The summary I have just made can be considered as being the special law for the *Gamasids* and the Ixodids, the only families of acarians I have studied up to this time.

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5. *On the Nesting Habit of* Atypus Niger, *a Florida Spider. By* Dr. McCook.

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6. *On Cephalodiscus. By* S. F. Harmer.

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7. *On some new types of Madreporarian Structure. By* G. Herbert Fowler, *B.A., Ph.D.*

The genera of Madreporaria, of which the anatomy has been hitherto studied, appear to fall into two divisions, the one consisting of solitary forms and of colonies in which the calices are free; the other including genera in which a cœnenchyme, or common skeleton, is present: in the former division the body-wall is supported by peripheral lamellæ of the mesenteries, in the latter on the spines or echinulations of the cœnenchyme. (Fowler, 'Anatomy of the Madreporaria,' iii. 'Q. J. Micr. Sci.,' 1887.)

Madracis asperula, however, forms a cœnenchymatous colony in which the septa project somewhat above the general surface, and the presence of both means of support for the body-wall appears to be correlated with this fact, *Madracis* thus being morphologically intermediate between such forms as *Caryophyllia* and *Seriatopora.*

Amphihelia ramea, an imperforate coral with free calices, varies from the normal types in possessing a canal-system between body-wall and corallum, these being otherwise in contact; while the peripheral lamellæ of the mesenteries are only recognisable immediately round the lip.

In *Stephanophyllia formosissima* also the so-called costæ or ridges of coral to which the mesenteries are attached are in direct contact with, and form the only means of support for, the body-wall, this genus bearing the same relation to the *Eupsammidæ* as *Amphihelia* to the *Oculinidæ.* In the formation of strong muscle-bundles between synapticulæ, as in some minor points, *Stephanophyllia*

approaches *Fungia.* In this and some other genera may be detected laminated offsets of mesogloea into the coral, for firmer attachment of the mesentery, such structures having been erroneously described by Mr. W. L. Sclater in *Stephanotrochus,* and probably by Dr. von Heider in *Dendrophyllia,* as calicoblasts.

8. *The Rôle of the Heart in Vertebrate Morphology.* *By* Dr. C. S. MINOT.

9. *On the Structure of the Human Placenta.* *By* Dr. C. S. MINOT.

10. *A New Species of Virgularia.* *By* Major PLANT.

11. *On some Rare and Remarkable Marine Forms at St. Andrews Marine Laboratory.* *By* Professor MCINTOSH.

12. *On the Development of the Ovary and Oviduct in certain Osseous Fishes.* *By* EDWARD E. PRINCE.

13. *On the Luminous Larviform Females in the Phengodini.* *By* Professor C. V. RILEY.

Certain interesting phosphorescent coleopterous larvæ reaching $2\frac{1}{2}$ to 3 inches in length have been well known to occur in America ever since Baron Osten Sacken first minutely described them in 1862, and discussed their affinities between the Elateridæ, Lampyridæ, and Telephoridæ. The author gave a minute description of these larvæ, calling attention particularly to the horizontal head, protruding labium, falciform, grooved, and untoothed mandibles inserted on the sides of the head, certain ventral conchoid depressions, minute dorsal stigma-like glands opening by a crescent slit between the joints, and the lateral spiracles.

The great interest attaching to these larvæ is not so much in their luminosity as in the fact that a portion of them are now known to be true and perfect females of Phengodini, which have, until recently, been represented in coleopterological collections in the male sex only. The history of this discovery furnishes another instance of simultaneous and independent observations on the same point in different parts of the world. In 1883, in conjunction with one of his assistants, Mr. E. A. Schwarz, he had arrived at this conclusion in Washington, with the intention of some time publishing the facts upon which it was based, when the same conclusion was being verified by Dr. Hieronymus, of Cordova, and the announcement anticipated by him and by Dr. Haase in 1885.

The author has been accumulating material since 1869 with notes, and has critically examined in all some thirty different lots in his own collection at the National Museum and in the collections at Philadelphia, Boston, and Cambridge. These all belong to *Phengodes* and *Zarhipis,* with the exception perhaps of Osten Sacken's No. 2, which may be *Spathizus.* The differences between the larva proper and the adult female are so slight that it would be difficult to separate them without some absolute index. The author had been fortunate in obtaining undoubted females, coupled with their males, of *Phengodes laticollis* and *Zarhipis riversii,* and in both genera there were absolutely no other structural differences between larva and adult female than the somewhat shorter (relatively) mandibles and tarsal claw in the adult.

In reference to life-history, the food of Zarhipis is known to be myriapods. The eggs in both genera are spherical, translucent, and laid in masses in the ground; the newly hatched larva in both are structurally identical with the parent, and the female larva goes through a pseudo-pupal state prior to the final molt. Nothing is yet known of the male larva and pupa, and the author only conjectures that certain darker, more slender larvæ, structurally identical, belong to this sex.

The author, in conclusion, discussed the bearing of the facts presented on the theory of evolution. We have many forms of degradational females in hexapods, and we have true larval reproduction; but he considers that the females of the Phengodini offer the most remarkable instances of imaginal or adult characteristics associated with such truly larval characters. 'In this larviform female of the Phengodini we get a glimpse, so to speak, into the remote past, from which has been handed down to us, with but little alteration, an archetypal hexapod form which prevailed before complete metamorphosis had originated; while, on the other hand, her male companion, during the same period, has developed wing-power and the most elaborate and complex sensorial organs—the eyes and antennæ in these beetles being among the most complex of their order.

'Whether we believe that the female Phengodes has never reached beyond her present form—*i.e.*, represents a case of arrested development—or that she has retrogressed from a higher type where the sexes were more nearly alike, one thing is, I think, self-evident, viz., that there is direct relation between the phosphorescence and the remarkable differentiation of the sexes; and, further, that such relationship is explicable and full of meaning on evolutionary grounds, and that the theory of natural selection accounts for the facts better than any other.'

SUB-SECTION BOTANY.

1. *On Cramer's Gemmæ borne by* Trichomanes alata. *By* Professor F. O. BOWER.

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2. *On some points in the process of Secretion in Plant-glands.* *By* WALTER GARDINER.

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3. *On Bennettites, the Type of a new group between Angiosperms and Gymnosperms.* *By* Count SOLMS-LAUBACH.

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4. *On the Presence of Callus-plates in the Sieve-tubes of certain gigantic Laminarias.* *By* F. W. OLIVER.[1]

SUMMARY OF RESULTS.

I. That in all *Laminariaceæ* the medullary string contains trumpet-hyphæ.

II. That in *Macrocystis, Nereocystis,* and one unnamed *Laminaria,* these trumpet-hyphæ form callus.

III. That in *Macrocystis* and *Nereocystis* sieve-tubes resembling those of *Cucurbita* occur around the central strand of hyphæ, and become in time obliterated by the development of callus on the sieve-plates.

IV. That the callus, both of the sieve-tubes proper and of the trumpet-hyphæ, is identical in its reactions with the callus of phanerogamic sieve-tubes.

V. That the callus in the trumpet-hyphæ is formed from the cell-wall.

VI. That *Macrocystis* and *Nereocystis* are rightly placed as nearly allied genera by systematists, their anatomical structure entirely confirming this determination.

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5. *On the Physiology of some Phæophyceæ.* *By* THOMAS HICK, *B.A., B.Sc.*

The author has made a series of observations and experiments in the larger brown seaweeds found on the British coast for the purpose of determining whether

[1] Vide *Annals of Botany,* vol. i. pt. 2 (1887).

their physiological processes present any special features. The species chiefly dealt with are *Fucus vesiculosus*, L.; *F. serratus*, L.; *Ascophyllum nodosum*, Le Jolis; *F. canaliculatus*, L.; *Laminaria digitata*, Lamour.; and *Himanthalia lorea*, Lyngb.

He finds that the cell-walls possess chemical and physical properties which are not met with in those of ordinary plants—although the fundamental composition is that of cellulose—and concludes that these properties enable the walls to act as a reservoir of water, on which the tissues may draw when the plants are exposed to desiccating influences. Experiments made to determine the quantity of water the walls may contain show it to be very great. A piece of *Ascophyllum nodosum*, Le Jolis, which when dried weighed 0·65 gramme, absorbed artificial sea-water until the weight reached 1·56 gramme, a gain of 140 per cent. Another piece, which weighed 0·78 gramme, increased in fresh water to 2·53 grammes, showing a gain of 225 per cent. Similar experiments, made with pieces of *Himanthalia lorea*, Lyngb., showed a gain ranging from 200 to 240 per cent. There is thus some difference in the quantity of water that can be stored up in the cell-walls of different species, but it is sufficiently large in all cases to prevent injury from desiccation when the plants happen to be left high and dry by the falling tide.

The function of absorption is performed, as in most aquatic plants, by the whole surface. This is true both for liquids and gases. It is a significant fact that neither stomata nor intercellular spaces have hitherto been met with in these plants. The absence of these structures is usually correlated with the aquatic habit and the consequent non-existence of transpiration. But in aquatic phanerogams, such as *Myriophyllum*, *Hippuris*, *Hottonia*, *Nymphæa*, *Alisma*, *Potamogeton*, and others, we have a well-developed system of intercellular spaces which includes large chambers filled with air. Hence the absence of these structures in the brown sea-weeds can scarcely be due to the aquatic habit alone. It ought rather, perhaps, to be correlated with the absence of any necessity for mechanical assistance in maintaining the erect position, and may prevent transpiration when the plants are exposed, but in any case it proves that intercellular spaces are not indispensable for respiratory purposes, and that in the plants under consideration the absorption of gases is performed by the superficial cells alone.

The absence of transpiration is *à priori* evidence that there is little or no movement of water from below upwards, and experiment shows positively that such is the case. Water and other fluids are readily conducted laterally from the surface inwards, but not in the longitudinal direction.

The metabolic processes of the brown sea-weeds, especially those connected with assimilation, present some interesting and important features. In the first place, careful search has hitherto failed to show in them any trace of starch. The following species have been specially examined with respect to this point, and all agree in giving only negative results:—*Fucus vesiculosus*, L.; *F. serratus*, L.; *Ascophyllum nodosum*, Le Jolis; *F. canaliculatus*, L.; *Halidrys siliquosa*, Lyngb.; *Himanthalia lorea*, Lyngb.; *Laminaria digitata*, Lamour.; *L. saccharina*, Lamour.; *Desmarestia aculeata*, Lamour.; *Leathesia tuberiformis*, Gray; *Chordaria flagelliformis*, Ag.; *Mesogloia virescens*, Carm.; *Sphacelaria cirrhosa*, Ag.

But if starch is absent the proteids are present, and generally in considerable quantity, showing that the constructive metabolism which gives rise to these bodies—proteosynthesis, as it may be called—is tolerably active in these plants.

The significance of these peculiarities is probably great, but is by no means clear. Millardet has shown that the *Fucaceæ* contain three pigments—viz., chlorophyll, phycoxanthine, and phycophæine. Hansen has recently confirmed and extended Millardet's observations, and finds that the chlorophyll of the higher plants is composed of two constituents, a green and a yellow, the latter of which is identical with the phycoxanthine of the *Fucaceæ*. Hence it is the presence of the phycophæine which distinguishes the assimilating organs of the *Fucaceæ* from those of ordinary green plants, and which may be directly or indirectly responsible for their peculiar action.

The plastic materials being then wholly or for the most part proteinaceous, the arrangements for their distribution through the plant must be adapted to their chemical and physical properties. This is found to be the case. In the *Fucaceæ*,

as the author has shown elsewhere, the medullary and cortical tissues have an elaborate system of protoplasmic connections between the contents of the cells, which give the rows of cells more or less the characters of sieve-tubes. Now in the higher plants indiffusible proteids are conducted from the place of manufacture to the place of consumption or storage along the sieve-tubes in the phloëm. Hence there can scarcely be a doubt that what may be called the sieved tissue of the *Fucaceæ* is to be correlated with the large quantity of proteids they contain, and the necessity that arises for their distribution to different parts of the thallus.

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6. *On Assimilation and the Evolution of Oxygen by Green Plant Cells. By* Professor PRINGSHEIM.

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7. *Some Words on the Life-history of Lycopods. By* Dr. M. TREUB.

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8. *On a point in the Morphology of* Viola Tricolor. *By* Professor BAYLEY BALFOUR.

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9. *On the Morphology of some Cæsalpineæ and the Value of Morphological Criteria. By* Professor HARTOG.

TUESDAY, SEPTEMBER 6.

The following Reports and Papers were read:—

1. *Discussion on the Present Aspect of the Cell Question.*

Professor Schäfer opened the discussion, which was continued by Professors Lankester, Krause, H. M. Ward, Carnoy, and Hartog, and Messrs. Gardner and Sedgwick.

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2. *On Polar Bodies. By* Professor WEISMANN, *and by* Professors LANKESTER *and* KRAUSE, Messrs. GARDNER, SEDGWICK, H. M. WARD, CARNOY, *and* M. HARTOG.

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3. *Report of the Committee on the Herds of Wild Cattle in Chartley Park and other Parks in Great Britain.*—See Reports, p. 135.

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4. *Further Experiments upon the Protective Value of Colour and Markings in Insects. By* E. B. POULTON.

The experiments undertaken in 1886, of which a short account was given in a paper read before Section D at Birmingham, led to such interesting results that I determined to renew the investigation during the present year.[1] At the same time the range of the inquiry has been widened, and for the first time a mammal has been included in the list of insect-eating vertebrates used in the experiments. For this purpose a marmoset has been employed, and this animal appears to be highly insectivorous. With the kind help of Mr. A. G. Butler I have been able to add largely to the number of experiments made with birds, and these results have been especially needed. In addition to the species of lizards and frogs made use of last

[1] For the complete account of the experiments in 1886, see a paper by the author in *Proc. Zool. Soc.*, London, March 1, 1887, pp. 191–274.

year I have also experimented with a chameleon and a salamander. The comparison of the results obtained from these different groups of insect-eaters is extremely interesting. In nearly all cases there is complete concurrence in their treatment of highly coloured nauseous insects. But there are great differences in the relative ease with which the different groups can be induced by hunger to eat distasteful insect food.

The frogs and the birds appear to be the least scrupulous in this respect. It seems probable that the superficial skin of the frog is more delicate than the lining of the oral cavity. Thus the hymenopterous larvæ of *Cræsus septentrionalis* and *C. varus* were eaten in considerable numbers, but the face was carefully wiped with the paw after being touched by the everted ventral glands of the larvæ. I am inclined to think that lizards are less unscrupulous in this respect than the most completely insect-eating birds. Mammalia (*i.e.*, the marmoset) appear to be far more difficult to please than any of the other groups. The above arrangement accords well with what is known on other grounds of the development of the sense of taste in the vertebrate classes. I will now bring forward a few of the instances which support the above-mentioned conclusions. The marmoset would never touch a hairy or spinous larva of any kind: this was because of the presence of the structures themselves, for the same species was alwas eaten in the pupal stage. All the other vertebrates will sometimes eat hairy larvæ. Birds have a special advantage in their power of getting rid of unpleasant appendages, such as hairs or wings. Large lizards will eat unpalatable insects which are often refused by smaller ones, probably because the former can swallow their prey without so much biting, and thus without tasting it so much. Ladybirds were eaten by the nightingale, and by frogs when very hungry; hitherto they have been invariably refused by the other vertebrates. The green larva of *Pieris rapæ* was eaten but disliked by the marmoset, relished by the lizards. The hairy larva of *Acronycta aceris* was eaten by birds, refused by lizards and marmoset. The hairy larva of *Orgyia antiqua* was eaten by birds, but refused by lizards, except on one occasion when two lizards fought over the larva, and in the struggle tore out the hairs incidentally. An experiment with this latter larva gave a very probable interpretation of the meaning of the hairy tufts on many Bombyx larvæ. A lizard seized the larva by one of these tufts, which immediately came out, leaving the lizard with a mouthful of hairs. After this it did not again touch the larva. These tufts are placed on the back in the part where larvæ are nearly always seized; being formed of very closely approximated fine hairs of the same height the whole tuft suggests a solid part of the animal rather than a mass of loosely fixed hairs. The following conspicuous nauseous forms have been eaten when the vertebrates have been hungry:—

Euchelia jacobææ—larva, by lizard.	*Diloba cæruleocephala*—larva, by lizard.
Pygæra bucephala— ,, ,,	*Liparis salicis*— ,, ,,
Porthesia auriflua— ,, ,,	,, ,, imago, by lizard and marmoset.
Zygæna filipendulæ—imago, ,,	*Abraxas grossulariata*—imago, by lizard.
,, *trifolii*— ,, by frog.	

L. salicis (imago) is evidently very distasteful, but the very similar, although smaller, *P. auriflua* (imago) is palatable; and the latter probably benefits by the reputation of the former. Thus the marmoset when very hungry ate the former, although it was much disliked; immediately afterwards the mammal refused the latter, although on another occasion he ate as many as four of these moths with evident relish. Highly gilded pupæ of *Vanessa urticæ* were eaten with relish by birds and the marmoset, and it is clear that the appearance does not in this case indicate an unpleasant taste, as has been suggested. The spider-like larva of *Stauropus fagi*, in its terrifying attitude, somewhat impressed a lizard and the marmoset, but not to such an extent as to prevent the larva from being eaten. This was to be expected, for both animals will eagerly devour spiders. Such effect as was produced was due to the suggestion of no ordinary English spider, but one of much greater size and with the terrific aspect highly idealised. The terrifying larva of *Cerura vinula* certainly frightened the marmoset, and either its appearance

or the secretion of formic acid greatly affected the lizards. The terrifying but quite harmless larvæ of *Chærocampa elpenor*, which is known to frighten all but the boldest of birds, as Weismann has shown, was offered to a large lizard. The latter examined the larva most cautiously and many times before touching it; then it bit the larva gently, and retired to watch the effect, repeating this process several times. Finally, finding that nothing happened, it seized the larva and soon swallowed it. The effect produced by this serpent-like larva was not due to its size, for the equally large larvæ of *Smerinthus ocellatus* were seized at once. The imagines of *Sesia bembeciformis* and *S. apiformis*—resembling hornets—were offered to a lizard. On the first occasion the moth was approached with the greatest caution, examined carefully, and seized by the head and thorax, just as though it possessed a sting. At the same time the lizard was evidently suspicious of the apparent wasp or hornet at first sight. When a few days later a second moth was offered to the same lizard it was immediately seized without any caution or hesitation. The lizard had learnt its lesson. Instances of this kind support the belief that insect-eating animals have no instinctive knowledge of the palatable or unpalatable or dangerous character of their prey, but that they learn by experience. Thus the chameleon was offered a bee, which was caught at once with the tongue; as the organ was withdrawn the chameleon was stung, and shook the bee off; after this it would never touch a bee again. Similarly with many conspicuous nauseous insects; they were generally caught once, but rarely a second time. Now if such instinctive knowledge existed, the chameleon, above all, might be expected to possess it, because of the manner in which it catches insects. Shooting its prey from a considerable distance, it can rarely gain any knowledge of a new insect without, so to speak, committing itself; whereas other lizards can make use of the tactile sense in their tongues, while their sense of smell must be more efficient because of their greater proximity before capture. It appears, however, that the chameleon brought among the insects of a new country relies solely upon a good memory and powerful sight: and these are so efficient that a single instance of each species of insect is sufficient for a thorough education. If, however, the chameleon depends upon instinctive knowledge for the avoidance of nauseous insects in the countries where it is indigenous, we should not expect that its education in strange countries would be so rapid and complete as it has proved to be.

All the species of the genus *Zygæna* hitherto tested are nauseous, and all are conspicuous and strikingly similar, so that it is probable that we have here an instance of divergence checked by the advantages which follow from simplifying the education of enemies by setting them one pattern to learn instead of several. Instances of this are well known in other countries, but this is the first example in our own fauna.

Among all the experiments previously recorded there occurred no instance of an unpalatable imago which had been palatable in earlier stages. I have paid especial attention to working through many histories in this way, and as a result I have found one such instance. The larva of *Arctia caja* is unpalatable because of the presence of hairs, but apparently not otherwise; the pupa is palatable, while the imago is highly conspicuous and extremely nauseous.

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5. *The Secretion of Pure Aqueous Formic Acid by Lepidopterous Larvæ for the purpose of defence. By* E. B. Poulton.

It has been long known that the larvæ of the genus *Cerura* (*Dicranura*) have the power of ejecting a colourless fluid from the mouth of a gland which opens on the prothoracic segment. The latter segment is dilated when the larva is irritated, so that the fluid is thrown in a forward direction, and for a distance of several inches. When the larva is touched the head and anterior part are immediately turned towards the source of irritation, and the fluid is thrown in this direction. In 1885 I found that the secretion was strongly acid to test paper, and that it caused very strong effervescence when placed upon sodium bicarbonate; while a

little later I showed the fluid to Professor Wyndham R. Dunstan, who told me that the characteristic smell of formic acid could be plainly detected. This opinion was further confirmed when it was found that silver nitrate was readily reduced by the secretion.[1] In 1886 I obtained a larger number of larvæ, and with the kind help of Mr. J. P. Laws I was enabled to show that the secretion contains about thirty-three per cent. of anhydrous acid. All the well-known qualitative tests were applied to the secretion and to the alkaline salts obtained by neutralising with a standard alkali. Among other tests the secretion was found to dissolve the oxide of lead, a white crystalline salt being deposited. Although only a very minute weight of this was obtained, Professor Meldola kindly offered to estimate the amount of lead present in the salt. The weight was found to correspond to one of the basic formates of this metal, formed by the action of the normal formate upon the excess of oxide. During the past summer I have had a very large number of these larvæ, and the investigation has been continued with larger amounts of secretion. The pipette has been applied for the removal of secretion between 500 and 600 times, and between 20 and 30 volumetric determinations have been made. A mature larva which has not been previously irritated will eject ·050 grm. of secretion, containing about 40 per cent. of anhydrous acid. Half-grown larvæ eject nearly as much, but the fluid is weaker, containing about 33 to 35 per cent. of acid. The rate of secretion is comparatively slow; *e.g.*, two days and a half after ejection two large larvæ only yielded together ·025 grm. of secretion. Two mature captured larvæ, to which the eggs of a parasitic Ichneumon had been affixed, only ejected ·035 and ·045 grm. of secretion, having incompletely made up for the amount lost during the attack of the hymenopterous insect. Starvation lessens the amount of secretion and also decreases the proportion of acid; but probably both these effects are due to general health, and do not imply the direct formation of the acid from the food. The different food-plants—poplar and willow—do not make any difference in the amount or strength of the secretion. About half the total quantity of secretion obtained was made use of in preparing a relatively large amount of the normal formate, which is now in Professor Meldola's possession. The weights of the constituent elements will be determined by combustion. [Since the above was written, Professor Meldola has analysed the salt, and finds that it is formate of lead in a state of almost complete purity, although he believes that a minute trace of some other lead salt is also present.] The rest of the secretion has been used for other exact methods of estimation and analysis under the kind direction of Mr. A. G. Vernon Harcourt, the work having been conducted in his laboratory at Christchurch. Mr. Harcourt suggested that it was most important to prove that the amount of acid shown to be present by volumetric analysis is formic acid, and nothing else. This proof was obtained in two ways. (1) A certain weight of the secretion was divided into two parts; the amount of acid in one of these was determined by the volumetric method, while the other was decomposed by strong sulphuric acid, and the carbon monoxide which was evolved was exactly measured in the apparatus for gas analysis, and the amount of formic acid present was calculated from the data thus obtained. The two percentages nearly corresponded, and as the latter was the higher it was obvious that no other acid could be present. (2) A certain weight (·186 grm.) of secretion was heated in a tube over a water-bath, and after drying at 100° C. only ·0004 grm. of solid residue remained, and this was probably accidental. The rest of the fluid was distilled into a tube containing carbonate of lead, and this was afterwards heated to 100° C., and the water collected in drying tubes. As a result: the increase in weight of the latter and the tube containing lead carbonate, the weight of formate of lead obtained from the latter, and of sulphate of lead obtained from the formate—all corresponded almost exactly to the weights which would have been given by pure aqueous formic acid having the composition: water, 62·5 per cent.; formic acid, 37·5 per cent. It therefore appears certain that the secretion consists of a strong aqueous solution of very nearly pure formic acid.

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[1] See *Trans. Ent. Soc.* London, 1886, pt. ii. June, pp. 156, 157.

6. *On* Icerya Purchasi, *an insect injurious to Fruit Trees.* *By* Professor Riley.

The species is the most polyphagous of coccids, living on a great variety of plants, and thriving particularly on acacia, lime, lemon, orange, quince, pomegranate, and walnut. It is capable of motion at all stages of development after hatching, and can survive without food for a long period. These characteristics have rendered it the most grievous enemy which the fruit-grower has to contend with in Australia, New Zealand, South Africa, and California. It is believed to have originated in Australia, and to have been introduced into other parts of the world upon living plants. But in endeavouring to get accurate data for this belief I have been led to question the specific value of *Icerya Purchasi*, Maskell, as compared with *Icerya sacchari*, Signoret. This last infests sugar-cane in the islands of Bourbon and Mauritius, and, on the hypothesis that *Purchasi* is a synonym of it, the wide distribution of the pest through the sugar trade becomes at once intelligible, as it is a common practice in the Pacific islands to insert a piece or pieces of the cane in the hogshead or other packages for the purpose of facilitating the drainage of syrup; that is an accompaniment of the unrefined sugars produced there.

Thus the question of synonymy bears directly on the original source of this pest, and this is important to us practically in any study of the natural enemies of the species with a view to their artificial introduction into those countries which Icerya has invaded without its natural checks.

This Icerya, on account of the protection offered by the fluted waxy ovisac, and of its other characteristics already mentioned, is one of the most difficult of all insects to control, as few insecticides will reach the eggs.

In my official paper [1] will be found details of experiments whereby the difficulties have been surmounted in California by judicious spraying of kerosene emulsions and resin soaps, as well as by a combination of cyanhydric gas evolved from potassic cyanide, and carbonic gas evolved from sodic bicarbonate, used under a portable tent.

7. *On a Luminous Oligochæte. By* Professor Allen Harker, *F.L.S.*

The author described a remarkable phenomenon of luminosity or phosphorescence exhibited on a large scale on a peaty moor in Northumberland at an elevation of 600 feet. The imprint of recent footmarks on the peaty ground shone with a brilliance recalling similar effects on sea-shores described by numerous authors, while the feet of the horses of a riding party galloping across the wet peaty soil threw off the luminous mud in what appeared to be showers of white glowing fire. An examination of the peaty soil showed the presence of innumerable small Oligochæte worms, which by a variety of experiments, detailed by the author, were proved to be the producers of the luminosity. In a darkened room a single worm on being gently rubbed glowed like a fine streak of phosphorus. The worm is a small Enchytræus, but will be fully described.

8. *On the Hessian Fly, or American Wheat-midge,* Cecidomyia destructor, Say, *and its appearance in Britain. By* Professor W. Fream, *B.Sc., F.L.S., F.G.S.*

The Hessian fly was discovered in Britain in barley-fields near Hertford in July 1886, previous to which date there is no record of its occurrence in this country. During the present summer it has been traced over the greater part of England and Scotland, and the author found it on July 14 in fields of wheat and barley on the borders of South Wilts and South Hants.

The pest is a true two-winged fly (order, *Diptera*; family, *Cecidomyiidæ*), and its habits and life-history are described. As a crop scourge it has proved most disastrous in the United States, where only the Rocky Mountain locust

[1] *Report of the Entomologists, U.S. Department of Agriculture, for* 1886; Bull. 15 Div. of Entomology, U.S. Dept. Agr.

(*Caloptenus spretus*, Thomas), the cotton worm (*Aletia xylina*, Say), and the Chinch bug (*Blissus leucopterus*, Say) take precedence of it as noxious insects. The first serious attack in the United States happened a century ago (1786–89), and in 1788 the importation of American grain into Britain was prohibited until it was ascertained that the 'flaxseed' pupa-case travels in the straw rather than in the grain. The first authentic record of its occurrence in Europe was made in 1834 by J. Dana, who found it at Mahon, Toulon, and Naples. It is now known to exist in the south of France, and in Germany, Austria, and Hungary. Motschulsky noticed it in Russia in 1836; Lindemann again detected it there in 1879, and has since determined its presence over an area several times the size of Great Britain. It causes severe losses in southern and mid Russia.

The nature of the injury occasioned by the fly is described and illustrated with the aid of specimens and diagrams. The Third Report of the United States Entomological Commission (Washington, 1883) records disastrous losses. The fly has 'swept whole fields,' occasioned 'almost a total failure of the crops,' and has 'committed such ravages upon the wheat as scarcely to leave enough seed for another year.' In 1846 half a million bushels of wheat were estimated to have been destroyed in the western section of New York State; in 1886 the loss in this State was put at 20,000*l.*

The theory that the fly was introduced into the United States by Hessian troops during the War of Independence is regarded as untenable. Packard, discussing Wagner's results, concludes that the Hessian fly had appeared in the Eastern States before the Revolutionary War, that it has never been known to inhabit England or northern Europe, that it was not known even in Germany before 1857, that it has 'from time immemorial' been an inhabitant of wheat-fields on the Mediterranean coasts, that it most likely originated in this region, or farther east (in the probable original habitat of wheat and other cereals), and that it was introduced thence into the United States before the war. How it reached Britain is not known, but it probably came as 'flaxseeds' in straw used for packing or for litter.

Wheat, barley, and rye are the cereals attacked; oats appear to escape. The 'flaxseeds' or puparia have also been found upon timothy grass (*Phleum pratense*, L.), but there is no evidence of any other grass being attacked.

American observations indicate that the fly flourishes best in warm, moist seasons, so that the hot, droughty character of the recent summer can hardly have specially favoured it; in fact, it seems to have made headway under rather adverse conditions, and with one of our usual moist summers the attack would probably have been more severe. Many precautions have been suggested for the use of agriculturists with the object of minimising the attacks in future years.

Several species of Hymenoptera are parasitic upon the Hessian fly. Specially useful in this way are *Semiotellus destructor*, Say, one of the *Chalcididæ*, which deposits its eggs in the pupa of the Hessian fly, and *Platygaster error*, Fitch, which places its eggs within those of the fly. These minute parasites have done splendid service in the American wheat and barley fields, where they are as active friends to the corn-grower as are the aphis-eating lady-birds in this country to the hop-grower. It has been suggested that if the parasites have not accompanied the fly to Britain they should be colonised here. On August 11, however, from a 'flaxseed' in the possession of the author there emerged a chalcis fly, and other observers have confirmed the presence in this country of insect parasites of this much-dreaded crop scourge.

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9. *Note on the Hectocotylisation of the Cephalopoda.* *By* William E. Hoyle.

A female specimen of *Rossia Oweni*, received from the Granton Marine Station, had a number of spermatophores attached under the left eye.

These were small tadpole-shaped bodies, about 5 mm. in length. The head was entirely embedded below the skin of the animal, the slender tails producing the appearance of a bunch of hairs on the exterior. The apex of the head contains a

peculiar valve-like apparatus, the nature of which has not been completely examined. It is suggested as a probable account of the function of these structures that the sperm may be caused to issue from the long slender extremity of the spermatophore, and thus fertilise the eggs whilst they are being laid.

Some observations were added on the general systematic significance of the hectocotylus.

10. *On the so-called Luminous Organs of* Maurolicus Pennantii (*the British Pearl-sides*). *By* Ed. E. Prince.

This small and somewhat uncommon British fish is said in life to exhibit phosphorescence. The luminous organs or photo-discs are arranged, in the main, in two rows along the sides of head and trunk towards the ventral line. Each organ exhibits an eye-like structure, viz., a chamber closed in by a dense fibrous wall save at one point behind, and again in front, where it is provided with a clear lens-like plate. In front of this lens the integument passes and forms a cornea. The contents of the rounded chamber are composed of a network of glandular tissue, the nodal points of which form multipolar corpuscles. It is a peculiar kind of adenoid tissue, and is continuous with a large cylindrical mass of similar tissue occupying a large space below the abdominal cavity. This mass bifurcates and in the abdominal region proper forms a pair of lateral cylinders in close proximity to the lateral sensory line—the nerve supplying this line (a branch of the vagus) finally terminating, in fact, in the glandular meshwork. As the photo-discs have precisely the arrangement of a lantern—a translucent lens in front, with a protecting cornea, and a dense glistening reflecting wall behind—they are without doubt for luminous purposes; while as their energy becomes exhausted in use the photo-discs are doubtless reinforced from the large glandular stores within.

11. *On the Ova of* Tomopteris onisciformis, Eschscholz. *By* Ed. E. Prince.

The author holds that the figures and descriptions of previous authors do not correctly represent the facts—the ova arising not as single nucleated cells which subdivide and form compound masses, the so-called 'germ-cells' of Dr. Carpenter, but they appear to arise in a compound condition as groups of nucleated cells. One of these cells seems to grow at the expense of the rest, and thus the mature ovum of *Tomopteris* as in so many invertebrates is a product of several primary ova, which are used as pabulum.

12. *On a Ciliated Organ, probably Sensory, in* Tomopteris onisciformis. *By* Ed. E. Prince.

13. *Report of the British Marine Area Committee.*—See Reports, p. 95.

14. *A Forgotten Species of* Peripatus. *By* Professor F. Jeffrey Bell, *M.A.*, *Sec.R.M.S.*

In no account of the species of *Peripatus* does any writer ever make a reference to a species described by Professor Schmarda in his 'Zoologie' under the name of *P. quitensis*; in the second edition of this handbook, which is now lying before me, the species is figured on p. 76 of vol. ii. It is stated to come 'vom äquatorialen Hochland Südamericas,' and with a total length of 26 mm. it has thirty-six pairs of appendages. It is much to be desired that attention should be called to this species, so that travellers in or near the neighbourhood of Quito may make a careful search for it.

It is only by repeatedly directing attention to the existence of these rare and

not always easily found creatures that we can hope to obtain them. My persistency in appealing to Mr. E. P. Ramsay has been lately rewarded by the arrival of *P. leuckarti,* which has been found near Wide Bay, Queensland.

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15. *A Note on the Relations of Helminth Parasites to Grouse Disease. By* Professor F. JEFFREY BELL, *M.A., Sec.R.M.S.*

The death of a large number of grouse in the south-west of Scotland—or, to use less exact language, the prevalence of grouse disease in that region—has again brought into prominence the relation of tapeworms to the disease.

All those who have interested themselves in what has been written on the subject during the past year will agree that, in the minds of many writers, suspicion is still attached to the *Tænia* which is so frequently found in the intestine of the grouse; many naturalists had come to the conclusion that the presence of the tapeworm was in no sense the cause of the disease, whatever relation it might have directly to the death of the bird; but as this view is by no means so widely known or accepted as it should be, and as no real progress in the investigation can be made till disturbing elements are withdrawn, I may here summarise the evidence in favour of the benign, or at least non-malign, character of the tapeworm's presence, which I have lately obtained.

1. Of two grouse examined last October the better nourished had the larger number of tapeworms.

2. A grouse killed on August 12 this year had a perforation of the small intestine about 200 mm. beyond the end of the duodenal loop; all but one of the tapeworms, which were numerous in this bird, were found in the rectum; only one was found in the neighbourhood of the perforation, though that part of the gut is commonly and the other very rarely infested.

3. A grouse killed on August 15 this year was found to have sporadic patches of inflammation in the walls of the intestine and cæca; from 370 mm. of the intestine no less than twenty-four tapeworms were taken, but for the whole of this tract there was not the least trace of inflammation.

I may pass from these facts, which are quite sufficient to dispose of any theory as to the possibility of 'the secretion of the worms themselves' poisoning the blood, or indeed of any similar speculation, to note the relation between the 'disease' and the worm, which the weight of the late Dr. Cobbold's opinion has led many to regard as the cause of the disease. I only found the *Strongylus pergracilis* of Cobbold in one of three sets of birds examined between last autumn and this spring; in the third set, which consisted of a single bird from Sir W. Wallace's moor near Stranraer, the nematode was abundant; in the grouse killed on August 12 the worm was again abundant, but it appeared to be much less numerously represented in the one killed on the 15th. I think it should be borne in mind that the two latter birds were likewise from Sir W. Wallace's moor.

As the worm was absent from two sets out of five, and the three in which it was found all came from the same moor, it is quite impossible to point to *Strongylus pergracilis* as the cause of the disease.

The facts thus briefly set forth sufficiently dispose of the suspicion that helminth parasites are the cause of what is called grouse disease. The pathology of the affection or affections is beyond my province, and I have only to point out that the elimination of helminth parasites makes the class of observations already begun by Dr. Klein more necessary and urgent.

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16. *The Distribution of the Nightingale in Yorkshire. By* J. LISTER.

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17. *Report of the Committee on Provincial Museums.*—See Reports, p. 97.

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18. *On the Muga Silkworm and Moth* (Antheræa Assama) *of Assam, and other Indian silk-producing species. By* THOMAS WARDLE.

19. *Note on a Point in the Structure of* Fratercula Arctica. *By* FRANK E. BEDDARD, *M.A., Prosector to the Zoological Society of London.*

The posterior region of the oblique septa in this bird is largely muscular, as is stated by Huxley ('Proc. Zool. Soc.' 1882, p. 566) to be the case in the duck. This fact is an additional point of similarity between the representatives of these two orders of birds, which are placed by some naturalists near together. The presence of this muscular tissue in the oblique septum has, however, an obvious use, which, perhaps, rather does away with its value as evidence of affinity. The birds in question have an elongated sternum, and accordingly the abdominal muscles are necessarily less in extent than in many other birds. The process of respiration in birds depends to a large extent upon the abdominal muscles which depress the sternum, and therefore exert pressure upon the underlying air-sacs. In diving birds it is clear that there is, if anything, need of greater force for the expulsion of air than in flying or wading birds; the presence therefore of muscular fibres on the oblique septum enables this structure to be utilised as an additional depressor of the sternum.

Professor Huxley in the paper referred to compares the oblique septum of the bird to a structure in the crocodile, which consists of a broad thin muscle on either side arising from the pubis, and attached to ventral face of pericardium and to the ventral and lateral parts of the fibrous capsule of the stomach. He does not, however, lay special stress upon the particular resemblance which this structure bears to the oblique septum of the duck (and of the puffin) on account of the presence of muscular tissue in these birds. This is another instance of an ancient character being retained in a bird which is not one of the Struthionidæ, and is still further evidence against regarding these birds as the most archaic living form of bird.

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20. *On the Development of the Ovum in* Eudrilus.[1] *By* FRANK E. BEDDARD, *M.A., Prosector to the Zoological Society of London.*

The process of growth of the ovarian ovum in this aberrant earthworm differs in detail from the corresponding processes in any other annelid. In each 'compartment' of the ovary (see 'Proc. Roy. Soc., Edin.' 1885–6, p. 672), only a few germinal cells become ova; the remaining cells become for the most part metamorphosed into a semi-fluid mass of protoplasm. The nuclei of these cells are at first recognisable, but afterwards degenerate. A certain number of cells form a cap situated at one pole of the ovum, which when mature is surrounded by a single vitelline membrane. These changes in the germinal cells which do not become ova appear to indicate that they take a share in the nutrition of the ovum.

SUB-SECTION BOTANY.

1. *Alternation of Generations in Green Plants. By* J. REYNOLDS VAIZEY.

The object of this paper is twofold. First, to discuss the origin of alternation of generations in all green plants. Second, to see what effect such a view has on comparisons between the vegetative bodies of the oophyte and sporophyte of the same or different species.

Comparisons of the life-histories of *Coleochæte, Œdogonium, Sphæroplea, Hydrodictyon, Pandorina,* also *Chara* and the *Florideæ,* with that of the lowest mosses, show that in all these forms there is virtually an alternation of generations. In the lowest forms the sporophore generation is shown to consist of a simple mass of cells produced by the division of the oospore, each cell becoming sooner or later a spore which gives rise to the vegetative body of the oophyte; in the simplest case, namely, *Pandorina,* the oospore sometimes gives rise directly to a single sexual

[1] *Journ. Anat. Phys.* October 1887.

Pandorina cœnobium, or by division to several spores, each of which gives rise to a sexual *Pandorina* cœnobium.

Upon these comparisons it is suggested that alternation of generations arose from polyembryony, not, as according to Pringsheim's theory, by a process of differentiation from a number of individuals which were both sexual and asexual.

If this hypothesis is true it is then pointed out that the sporophyte, as it is more generally known in the mosses and higher plants, is a new body originating among the higher Algæ and lower Liverworts not genetically connected with the sexual body. Consequently the tissues of the sporophyte cannot be homologous with those of the oophyte, but may be analogous.

The *Florideæ* and *Characeæ* receive special consideration.

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2. *On a Curious Habitat of certain Mosses.* *By* C. P. Hobkirk, *F.L.S.*

The author exhibited specimens of two purely terrestrial mosses, *Mnium hornum* and *Polytrichum commune*, which he had found growing in a quarry pool near Dewsbury (West Riding of Yorkshire), quite submerged, and apparently of some years' growth. The only difference from the normal type was in the attenuation and elongation of the stems, the cell structure both of stem and leaves being unaltered.

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3. *Report of the Peradeniya Committee.*—See Reports, p. 96.

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4. *On the Constitution of Cell-walls and its Relation to Absorption in Mosses.*[1] *By* J. Reynolds Vaizey.

Polytrichum Commune, Linn.

I. *Cell-walls of Sporophyte.*—(1) Transverse section placed in iod. chlor. zinc; walls of epidermal cells brownish-yellow, rest of the cells more or less blue, the hypodermal sterome even slightly bluish in tint.

This is the case in both seta and apophysis. The guard-cells of *Stomata* on apophysis have a delicate cuticle well seen with iod. chlor. zinc; the internal part of cell-wall is pure cellulose, being turned blue with iod. chlor. zinc.

Chromic acid (strong) dissolves all the tissues more or less rapidly, leaving behind only the delicate cuticle, which is then distinctly seen as a membrane isolated from the tissues. The cuticle is dissolved by boiling in strong potash; is made distinctly visible and frequently partially separated from epidermis by chlorate of potash and nitric acid.

Anniline chloride + HCl turns the hypodermal sterome from brown to orange-yellow.

(2) Water is only absorbed by foot of seta. Water placed on capsule, apophysis or seta goes off as from an oily surface.

II. *Cell-walls of Oophyte.*—(1) Iod. chlor. zinc central strand of cells only turned blue.

Chromic acid not quite concentrated rapidly dissolves all the tissues; no trace of a cuticle or any cuticularised cell-walls to be seen.

Anniline chloride + HCl turns all peripheral tissues orange-yellow.

(2) Water sticks to leaves and stems, and is rapidly absorbed by them, as may be easily seen if only a few drops of water are left on the stem and leaves after immersion in water; after a few minutes it has all disappeared. A withered stem; placed in water, head foremost, it rapidly revives.

Hence it is seen that the seta and apophysis of sporophyte is cuticularised, and consequently gases only can be absorbed by those structures, and water is (as I have shown elsewhere) only absorbed by the foot. In the oophyte there is no cuticle, and consequently water can be, and is, absorbed by both stems and leaves.

[1] See also *Annals of Botany*, vol. i. No. 2.

The leaves of mosses are therefore seen to have a function differing very greatly from that of the vascular plants; while the apophysis of the sporophyte has exactly the same functions as the leaves of the vascular plants.

SUB-SECTION PHYSIOLOGY.

1. *Report of the Committee for the Investigation of the Secretion of Urine.* See Reports, p. 131.

2. *Report of the Committee appointed for the purpose of investigating the Physiology of the Lymphatic System.*—See Reports, p. 145.

3. *On the Development of the Roots of the Nerves and on their Propagation to the Central Organs and to the Periphery. By* Professor HIS.

It is about fifty years since Theodor Schwann, in his fundamental work on the animal cell, gave out the opinion that nervous fibres are formed by the connection of rows of cells. This opinion has for a long time prevailed among all histologists, and has also been adopted by the eminent embryologist that English science lost at so early an age, the late Professor Balfour, and by Professor M. Marshall and others.

Besides this older theory and that of Professor Hensen, which I can omit to-day, there is another, first brought up by Messrs. Bidder and Kupffer in the year 1858. These inquirers considered nervous fibres as direct outgrowths from central cells. I myself have been led by my own inquiries a long time ago to adopt this opinion, and I came, moreover, to the conviction that, while motor fibres grow out from the cells of the spinal cord and of the brain, sensitive fibres have their issue from the cells of the ganglions. In the last six years I have had the opportunity of verifying this supposition, and I should think that on this point discussion is no more possible. No motor cylinder axis, for instance, issues from a row of cells; everyone comes only from one cell situated in the spinal cord or in the brain.

The observations of Professor Balfour, of Professor Marshall, and others on cells in the path of motor nerves are completely true; it is also true that these cells are in some way engaged in the formation of nerves, but they have nothing to do with the cylinder axis; they form only the accessory parts of the nerves, the neurilemma and the sheath of Schwann. In the dog-fishes these accessory cells are very richly developed, while in the human embryo they appear slowly. Sections of human embryos are, therefore, much better suited to all the studies of the formation and the propagation of nervous fibres than the sections of dog-fishes and of many other vertebrates.

In the human embryo the first nervous fibres are to be seen during the fourth week, and the fibres emerging from the spinal cord appear a little sooner than the fibres coming out of the ganglions. At this time there can be distinguished in the spinal cord an outer and an inner layer of cells. The inner layer is more compact, and it only contains karyokinetic figures, while every cell of the outer layer sends out one fibre or one cylinder axis. The fibres of the dorsal half go forwards, forming partly the white commissure, partly longitudinal cords. The fibres of the ventral half run to the surface of the spinal cord; they pass out and unite so as to form the motor roots. Every root is formed by a certain number of fibres, all issuing from single cells of the corresponding floor of the spinal cord. There are in this early period no ramified processes of the spinal cells.

The brain part of the medullary tube shows also a separation between an outer and an inner layer of cells, and leaving out of consideration the fore-brain that we actually can pass over, every one of the outer cells seems also to send out

a cylinder axis. To a certain extent—namely, in the district of the rhomboid sinus—there is at the end of the first month a well-pronounced separation between the ventral and the dorsal half of the tube, the latter being of pentagonal shape, and its roof being formed by a very thin layer of cells.

All motor fibres of the brain, from the hypoglosse to the oculomotor, issue from cells of the ventral half of the brain tube, and there is in this point a perfect correspondence with the spinal cord.

As far as the inferior end of the rhomboid sinus the continuity of motor-fibrogenous cells is preserved; further upward these cells form certain groups, partly separated by cells that do not form motor roots. We have in this way the different motor centres of the 7th, 6th, 5th, 4th, and 3rd nerves.

The path that motor fibres follow in going out are more varied in the brain than in the spinal cord. Besides the accessory nerve of Willis all motor fibres of the spinal cord go out from the ventral side of the organ. In the superior part of the spinal cord many of the motor fibres run laterally to form the accessory nerve of Willis, and the same will be found in the lower part of the brain.

There is a long double row of fibres coming out; one of these rows is given by the roots of the hypoglosse, the other by those of the nerve of Willis. The inner separation of the nuclei in the motor territory is at this time not distinct. Hypoglossal fibres come from the more ventral, Willis's fibres from the more dorsal cells of this territory.

Going upwards, there are in the way of the hypoglosse only two nerves, the sixth and the third. In the course of the nerve of Willis we find the motor fibres of pneumogastric, glossopharyngeus, facial, and fifth nerve. But we find also more peculiar courses of the interior motor fibres. The fibres of the fourth nerve, coming out from a ventral nucleus, are going to the roof of the tube, and they cross each other. The fibres of the facial nerve, coming from a nucleus behind the auditory vesicle, form an interior arch before they reach the surface, and they come out only in front of the auditory vesicle.

The sensitive nerves and also the auditory nerve grow out of the ganglions. The cells of these organs become bipolar, and every one of them sends out two fibres, one going to the centre, one to the periphery. The central fibres coming to the spinal cord form generally a longitudinal bundle, the first beginning of the posterior column. A certain number of them go more or less directly between the cells of the spinal cord.

In the head, as is well known, four ganglion-masses are formed. Two of them, the ganglions of pneumogastric and of glossopharyngeus, are behind—two others, the facial-auditory and the trigeminus ganglion, in front of the auditory vesicle. These ganglion-masses send out fibres also to the periphery and to the brain. Besides the auditory nerve that spreads itself out near the point of its entry the four other nerves come to the surface of the brain. They change the direction of their fibres, and form in this way longitudinal bundles. The bundles are the origins of the ascending roots of the pneumogastric, the glossopharyngeus, and the fifth nerve. An ascending root of the facial nerve, or, more correctly, of the nerve of Wrisberg, has also been discovered in the brain of man by the most subtil investigations of Mr. Sapolini. All these ascending roots are in their first origin very short, and they grow by degrees longer and longer. Their position is at first very superficial; afterwards they become deeper by a series of foldings of the brain-wall.

The nerve-bundles formed by the motor and the sensory roots pass to the periphery. Every one of them is formed by fine fibres without nuclei, some connective cells being intermixed with them. The bundles are at first short and comparatively very thick. They grow by degrees, and some weeks pass before their last ends reach the periphery.

These first new trunks go straight in the direction in which they grow out, and when there is no obstacle they run a long way in a straight course. This is very conspicuous in the different nerves of the head, in the three muscular nerves of the eye, in the branches of the fifth nerve, and also in the pneumogastric nerve, which is going with its principal branch behind the brachial arches

in a direct way to the internal organs of the body. The nerves of the extremities reach by the shortest route their territory, and only by-and-by they are drawn out to their terminal length.

By secondary dislocations the nerve-trunks can be curved, and so the direction of their actual end and of their growing out can be altered. This is to be seen in the facial nerve and in many other nerves of the body. When the different nerves that are near together grow out in a different direction they will cross, partly unite, and form anastomoses. The relations in the angle between the head and the body give a striking illustration to this assertion.

An outgrowing nerve can find obstacles in its straight way. In this case it will undergo a deviation, and this deviation, not being the same for all its fibres, will bring about a division of the trunk. Cartilages, blood-vessels, and similar things act as such obstacles. The nerves are not all formed at the same time, the nerves of the neck and of the hind part of the head being formed the first.

I have not followed as yet the history of the ramified processes of the nerve-cells. They are formed much later than the cylinder-axis fibres, and the conditions of their spreading out will be found more complicated. Every one of these fibres must have one cell as origin, but it seems to me very improbable that it must generally have also terminal cells, and in this point I agree with the opinions of Mr. Golgi and Mr. Forel.

I should now enter upon the discussion of the morphological position of the nerves. This, however, would take me too long, because different principles would have to be fixed, and I confine myself therefore entirely to the facts I communicated. I shall only give one general remark—I could show that the way which Nature follows in forming the nervous system is very simple. There is nothing more simple than the formation of the process of a cell, nothing more simple than the straight outgrowing of these processes until they find an obstacle, or until they come to a terminal station. Nothing can be, I dare say, more rough than the fact that apparently accidental things, as a blood-vessel or a cartilage, should have an influence on the final arrangement of the nerves of the body. And this final arrangement gives at last a system of the most complicated organisation—a system which determines all our functions, both of body and of mind. And this system shows itself in the most delicate dependence on the general law of heredity.

The primary foldings of the blastoderm are of no less simplicity; their next consequences are to a great extent comparable to the consequences indicated by the geologist in the formation of our earth's crust; and nevertheless they determine all the further development of the body.

We can pronounce the general proposition that in her way to the formation of higher organisms Nature is not only passing through simple forms, but she is also using the most simple mechanical means; and I must think that in the great question of heredity the study of this means must obtain its full place.

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4. *The Morphology and Physiology of the Limb-plexuses.*[1] *By* A. M. Paterson, *M.D.*

In bringing this subject before the Section my object is not so much to enter into details regarding the plexus formation in mammals as to state the broad outlines of the results of some recent researches, and, if possible, to raise a discussion on the physiological and morphological aspects of the question.

These plexuses are constant in their presence in higher vertebrates, but no satisfactory reason for their existence is assigned either by the anatomist or the physiologist. The object of my inquiry is, why do they exist? Why does not any given nerve (*e.g.*, the human anterior crural) spring from a single primary division

[1] This paper contains a summary of parts of two already published:—(1) *Journal of Anatomy and Physiology*, vol. xxi., 1887, 'On the Limb-plexuses of Mammals'; (2) *Quarterly Journal of Microscopical Science*, August 1887, 'On the Fate of the Muscle-plate, and the Development of the Spinal Nerves and Limb-plexuses in Birds and Mammals.'

of a spinal nerve instead of from several? In other words, why does not one primary division contain within itself all the strands of the nerve? How is it that a nerve does not pass from the cord directly to the parts which it supplies, but, on the contrary, gives fibres to and gets fibres from adjacent nerves in its course?

With the object of discovering if there is any fundamental plan upon which the formation of the plexuses and the distribution of the nerves is based, complete dissections were made of ten different animals—porcupine, rat, koala, rabbit, guinea-pig, cat, camel, brindled gnu, capucinus, and entellus monkeys.

These dissections have led to certain conclusions regarding the constitution of the plexuses, which are supported by a reference to the condition of things which obtains in man; and, still further, to the formulation of a general hypothesis which appears adequate to explain their existence.

Without describing *minutiæ*, it is enough to say that by an analysis of the plexuses of the fore and hind limbs one finds on the one hand that there are certain minor differences in the arrangement of the nerves in different cases; on the other hand that there are certain fundamental points in which all agree.

(A) The points of difference are, speaking broadly, two:—

1. In the number of nerves entering such plexus.
2. In the position of the limb-plexuses in the series of spinal nerves.

1. Examining the number of nerves which enter into the composition of the brachial and lumbo-sacral plexus, both in the animals dissected and in all other recorded cases to which I have had access, I find that *five nerves, or thereabouts*, are engaged in the formation of the nerves of distribution to the limb proper. The number, however, varies in different animals, being sometimes more and sometimes less than five.

In the Brachial Plexus.—Five nerves entered into the formation of the plexus in five cases, four in four cases, and in the entellus monkey six nerves assisted in forming the plexus.

In the Lumbo-sacral Plexus.—In all cases but one five nerves were engaged in forming the branches which supplied the limb proper. In this category the ilio-hypogastric ilioinguinal, small sciatic, and internal pudic are omitted, as only one of them (the small sciatic) supplies any portion of the hind limb; and in most of the animals that nerve merely supplies the skin of the buttock and upper part of the flank. In other recorded cases I find the number of plexus-forming nerves in relation to the hind limb to vary between four (in thylacine) to seven (in man).

While, however, there are slight individual variations, the number in all cases is *about five*. This fact gives support to the late Professor Goodsir's hypothesis, that the mammalian limb derives elements from five vertebral somites.

2. With regard to the second point of difference, the position of the limb-plexuses in the series of spinal nerves, the discrepancies are only slight.

In the brachial plexus the nerves which form it are always the sixth, seventh, eighth, and ninth spinal nerves, with, in addition in certain cases, the fifth or fourth. Occasionally in man the tenth nerve also joins the plexus.

In the lumbo-sacral plexus there is at first sight no regularity in the arrangement of the nerves entering into it, with regard to the vertebral segments. The plexus for the hind limb may be formed wholly by lumbar nerves or by the addition of sacral nerves as well.

This discrepancy is due to two causes: first, the varying number of thoracico-lumbar vertebræ; and secondly, the varying position of the lumbo-sacral articulation. It disappears to a certain extent when the numbers of plexus-forming nerves are counted in relation to the series of the spinal nerves. When this is done it is seen that there is still considerable variation, from the twenty-first to the twenty-ninth spinal nerves. The twenty-fifth nerve is the only one present in every case.

(B) Points of agreement:—

Notwithstanding these minor differences, there are certain fundamental points of agreement in the composition of the limb-plexuses of the limbs and in all the animals dissected:—

1. In the arrangement of the nerves in the plexuses.
2. In the distribution of the nerves in the limbs.

1. From the dissections made and an analysis of results the three following rules have been laid down:—

(*a*) The inferior primary divisions of the nerves entering the plexus divide into dorsal (posterior) and ventral (anterior) branches.

(*b*) Dorsal branches *always* combine with dorsal branches, ventral branches with ventral branches, to form the nerves of distribution.

(*c*) The essential constitution of a nerve of distribution consequently never varies. A nerve arising from a combination of the *dorsal* divisions of certain nerves in one animal is never found in another to spring from the *ventral* divisions of these or any other nerves, and *vice versâ.*

These three deductions are supported by an examination of both brachial and lumbo-sacral plexuses.

In the case of the fore limb the inferior primary divisions of the nerves entering the plexus split first of all into dorsal (posterior) and ventral (anterior) branches; secondly, the dorsal branches combine to form one set, the ventral branches to form another set, of nerves of distribution.

In the case of the hind limb also there are two sets of nerves of distribution, one derived from a combination of dorsal or posterior branches, the other from ventral (anterior) branches of certain nerves.

In neither plexus do ventral divisions combine with dorsal divisions of adjacent nerves; in neither plexus does a nerve of distribution, derived in one animal from ventral divisions, in another case spring from dorsal divisions, and *vice versâ.*

The great sciatic nerve may be divided into three parts:—External popliteal, Internal popliteal, Nerve to hamstrings; and this I find is the rule in the animals dissected. They lie side by side, more or less closely bound together in a fibrous sheath, but with separate and distinctly different origins. The external popliteal when traced up to the plexus is seen to be formed by a combination of dorsal branches; the internal popliteal, of which the nerve to the hamstring muscles is to be regarded as a part, is derived from certain ventral branches of the nerves which form the plexus.

I have shown elsewhere that the same is the case with regard to the human great sciatic nerve, and in birds also the two popliteal nerves are separate up to their origins.

The nerves derived from the plexuses have, moreover, a fixed and definite relation regarding their position and order of origin, from before backwards.

2. Turning now to the distribution in the limbs of the several nerves derived from the plexuses, we find that a similar classification may be made from a consideration of the parts supplied.

The mammalian limb originates as a bud which springs from the ventro-lateral aspect of the body. It is at first directed downwards and outwards, and presents a dorsal, superior, or external surface; a ventral, inferior, or internal surface; and a preaxial and a postaxial border. In the centre a formation of cartilage occurs, which afterwards develops into the bones and joints of the limbs. Outside (and above and below) this cartilaginous framework muscular envelopes are formed, giving rise to a double dorsal and a double ventral layer.

Primitively then the limb presents a dorsal and a ventral surface, each consisting of cutaneous and muscular strata, and lying respectively above and below the cartilaginous framework of the limb. These muscular and cutaneous strata have to be supplied with nerves.

The subsequent changes in the limbs, of elongation, angulation, and rotation, along with the development of the muscular strata into complicated systems, produce important effects in the configuration and structure of the limbs; so that it is a difficult matter to make out the relations between the parts of the fœtal and adult limbs.

It is sufficiently clear, however, for our present purpose that, in the case of the fore and hind limbs respectively, the following parts in the adult mammal are

identical with, and developed from, the dorsal and ventral surfaces of the embryonic limb.

In the case of the fore limb the following parts are developed from the *dorsal* surface: the parts in the scapula, the extensor surface of the humerus (the back of the arm), the extensor surface of the radius and ulna (back of forearm), and back of hand.

From the *ventral* surface the following parts arise: the pectoral muscles, the flexor surface of the humerus (front of arm), the flexor surface of the radius and ulna (front of forearm), and the palm of the hand.

In the case of the hind limb, the region of the buttock, the extensor surface of the thigh, the front of the leg, and dorsum of the foot are equally continuous with, and developed from, the primitive *dorsal* surface. The parts on the inner side and back of the thigh (including the adductor and hamstring muscles), the back of the leg, and the sole of the foot represent the *ventral* surface of the original outgrowth.

Turning again to the nerves, we find that the parts of the fore and hind limbs, which are derived from the originally *dorsal* surface of the embryonic limb, are supplied by nerves of distribution, which are formed by a combination of dorsal divisions of the nerves forming the limb-plexus. In the same way those parts derived from the primitive ventral surfaces are supplied by nerves of distribution derived from combinations of the ventral divisions of the nerves entering into the plexus. This holds good *without exception* throughout the series of animals examined.

From a consideration (1) of the origin of the nerves and constitution of the plexuses, and (2) of the parts of the limbs supplied by them, viewed in the light of the development of the mammalian limb, the following hypothesis has been raised:—

That in a primitive condition of the limb, at an early period of development, the nerves have a simple arrangement and distribution in the simple bud; the more preaxial nerves supply the preaxial portion of the limb; the nerve postaxial, the postaxial portion; while the inferior primary division of each nerve engaged in forming the plexus or in supplying the limb divides into a dorsal and a ventral branch for the supply of the dorsal and ventral surfaces respectively of its own particular part of the embryonic limb.

The embryonic nerves become differentiated and complicated in their arrangement *pari passu* with the development of the muscular system, and the changes which take place in the production of the adult condition.

Positive proof of this hypothesis can only be obtained from an examination of the developing nerves in the embryo. This has been done in the chick, and to a certain extent in mammals also. In a more recent paper I have shown that (1) at the roots of the limbs the nerves divide into dorsal and ventral branches, which unite respectively with adjacent dorsal and ventral branches, and can be traced to the dorsal and ventral surfaces of the limb; (2) the formation of the plexuses and the passage of the nerves to the distal extremity of the limbs occurs before the differentiation of the tissues of the limb into muscular elements.

Conclusion.—From these data an adequate conception can, I think, be obtained of the fundamental formation of the limb-plexuses. An analysis of these plexuses in mammals has shown that in the production of the 'nerves of distribution' out of the 'nerves of origin' two events occur: (1) The nerves of origin divide into dorsal and ventral trunks. (2) These dorsal and ventral trunks subdivide and unite with the *corresponding* subdivisions of adjacent nerves to form the nerves of distribution. The first step has been shown to be the result of an embryonic condition—namely, a splitting of the original nerves into trunks for the supply of the dorsal and ventral surfaces of the embryonic limb.

The second step follows as a necessary result of the changes which occur in the limb in the production of the adult condition.

The bud which eventually forms the adult limb may be looked upon as the result of the fusion of a certain number (say five) of primary buds—prolongations from the ventrolateral aspects of certain vertebral somites. Each myotome is sup-

plied by a distinct and separate nerve in the first place. By the development and evolution of the simple embryonic dorsal and ventral strata of muscles, formed of mesoblastic tissue derived from the original somites, the complicated systems of muscles are formed which exist in the adult.

These changes taking place in the myotomes it follows that similar alterations will occur in the primitive nerves which supply them. The myotomes undergo fusion, elongation, contraction, and a complex muscular system results. The nerves distributed to the original parts of this complex system undergo similar changes; adjacent dorsal and ventral divisions become fused, and give rise to a compound nerve, from which *pari passu* with the development of individual adult muscles branches are given off to supply them. It follows, therefore, that as one muscle may be formed from some only of the myotomes implicated in the limb, the particular nerve for this muscle may arise only from a certain number of the nerves of origin. On the other hand, one muscle may represent the whole breadth of the surface of the primitive limb; in such a case the nerve supplying it will derive fibres from all the nerves entering the limb-plexus.

From these considerations it is concluded that, as this *first step* in the formation of a limb-plexus, the *division* of the nerves of origin into *dorsal* and *ventral* trunks is a *primary* process in the development of the limb; so the *second* step, the *interconnection* of these *adjacent dorsal and ventral divisions*, is a *secondary process in the same direction.*

The limb-plexuses, that is, the formation of the nerves of distribution from certain nerves of origin by the division and union of the latter, are entirely the effect of the mode of development of the limb itself. They possess no physiological significance. There is no reason to believe that a nerve-fibre divides in its course. Until the nerve breaks up into its terminal filaments there is no evidence to show that it does not exist as a simple and individual fibre from its origin in the spinal cord. In other words, it is not known that an axis cylinder divides dichotomously in the limb-plexuses, so as to connect a single cell in the spinal cord with two distinct and separate muscles, or parts of the same muscle. This being the case, the existence of these plexuses is not explained by a vague reference to 'the co-ordination of muscular action.'

The conclusion I would submit is that they are an integral part of the process of evolution and development of the limb. They result in a convenience of nature in the adult condition. They are due to the changes which produce that condition, concomitant with other processes, all tending to the conversion of the simple into the more complex.

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5. *The Normal Phenomena of Entoptic Vision distinguished from those produced by Mechanical Causes. By* BEATRICE LINDSAY, *Girton College, Cambridge.*

Experiments on the subject of entoptical vision, extending over a period of three years, have led me to believe that the difficulty which has hitherto been found in explaining the formation of entoptic images of retinal structure has been largely due to want of clear distinction between those images which are formed in accordance with the laws of optics, and those which are due to the specific energy of the optic nerve, exhibited when mechanical stimuli affect its peripheral branches. I have therefore framed the following classification of the entoptical images of parts of the retina, that may be obtained by various experiments. Those images in the list which are marked with an asterisk are, I believe, now for the first time described in their relation to the actual structure of the retina.

I. Entoptical images obtained by normal sight; distinguished by their vitreous lustre, semi-transparency, colour as of natural tissues, translucent or red, and absence under complete darkness.

1. Purkinje's figures.

2. Images of blood-corpuscles. These, the existence of which has been disputed, are apparent throughout the visual field, the theory of the non-vascularity

of the centre of the retina being thus disproved. They are approximately of such size as if seen by a one-eighth objective, and are red in colour when best seen. They appear under various circumstances of optical curvature, varying from far accommodation to the microscopic accommodation (effected, unlike the normal accommodation, by alteration of the curvature of the cornea itself) which is possible to the myopic eye when half-closed and squeezed by the eyelids; and the condition of their perception seems to be the absence of other clearly defined images from the retina, or perhaps from the combined field of vision—a condition fulfilled under the following circumstances: —(1) Far accommodation when the eye is confronted by a near object; (2) near accommodation when the eye is confronted by a far object; (3) *oblique* vision of a bright source of light; (4) slipping the eyes into a position in which the visual axes are parallel, so that the images of the two eyes blur each other. The circulation of corpuscles observed under these conditions is in all respects normal, its rapidity undergoing a variation with the rapidity of the pulse, as described by Vierordt.

Although the determining condition of the perception of images of the blood-corpuscles seems to be absence of other definite images from the retina, yet these images are, of course, brought into view and removed from it by alterations of focus in the eye. From the wide limits of accommodation under which the images are visible, as above stated, it will be understood, however, that they do not depend, except in a partial and indirect manner, upon accommodation brought about in the normal way. The delicate focussing by which they are attained is due, at least in the majority of instances and in the case of the best images, not to ordinary accommodation, but to what may be called *retinal accommodation*, viz., a backward movement of part of the retina accomplished *directly* by the muscles acting on the eyeball. The existence of such a mode of accommodation, which has been discussed by Professor Silvanus Thompson in another connection, is shown by the manner in which the images of blood-corpuscles occur. The major part of the circle of distinct vision is occupied by images of corpuscles, while its margin presents the image of some exterior object, of which the middle is wanting—a condition which corresponds exactly with the above-named theory that a portion of the retina is pulled back out of its place, a local alteration of its curvature being thus effected. The difficulty of explaining the manner in which images of the blood-corpuscles occur has been greatly increased by the fact that the strain of the muscles in producing this 'retinal accommodation' gives rise to pressure images of blood-corpuscles, which are confused with normal images if their different lustre is not carefully noted.

3. Rim of the *fovea centralis.*

4. Rim of the blind spot.

*5 and 6. Two layers, one of small, brilliantly transparent, and round, the other of larger, more irregular, and apparently reddish bodies, which probably, from their relative sizes and distribution with reference to the *fovea centralis*, correspond respectively to the peripheral and the proximal nuclear layer.

II. Entoptical images resulting from pressure, automatic or artificially applied: distinguished by their metallic lustre; by their colour, varying from pale yellow through pale green to electric blue or purple, according to the intensity of stimulation, possibly complicated with other causes; and by their visibility in the dark, although they are usually rendered more intense by the presence of the normal stimulus of light.

1. A series of images beginning with the large nerve-branches radiating from the blind spot, and extending finally to the terminal branchlets in the *fovea centralis.*

2. A second series, passing from the peripheral part of the retina to the proximal, beginning with an image of the outer nuclear layer,* and proceeding to an image of the ganglionic layer.*

3. A central grating, composed of sets of bright bars at right angles with one another, indicating structure of some kind in the *fovea centralis.*

4. Pressure images of blood-corpuscles, in the form of discs usually, often of dots, and occasionally of rings. Confusion of these, visible in darkness and favoured by unhealthy conditions, with the normal images of blood-corpuscles,

visible only by transmitted light, and best seen in the most healthy condition of the eye, has hitherto hindered the complete explanation of either.

*The two kinds of images, of the same corpuscles, can be accurately superposed by means of alteration in the curvature of the retina, produced by the action of the rectus muscles of the eyeball in the manner above described, which is apparent to consciousness as a strain on the eyeball.

*Pressure images and superposed normal images, arranged in a number of circular whirls in the area of the *fovea centralis*, show that the so-called non-vascular area of the retina is furnished with a highly complex system of capillary loops. These loops, which like the major part of the retinal capillary system, run vertical to the plane of the retinal layers, are apparently derived from the deeper or arterial plexus, which belongs to the ganglionic layer. They are doubled back upon themselves, so that the corpuscles in the looped end are seen in the form of a rapidly turning star as they turn round it; the reason of this arrangement is that there are here no venous branches to receive them, the venous or outer plexus, belonging to the inner nuclear layer, having ceased with the boundary of the *fovea centralis*, in the manner which is apparent in most injected preparations, and which formerly gave rise to the belief that the *fovea centralis* was a non-vascular area.

*5. Light-dots: these are minimal units of pressure stimulation which must not be confounded with what the Germans call 'light-dust,' the latter consisting (as appears from the description given by Helmholtz) in confused pressure images of blood-corpuscles, and being therefore made up of shining spots which are at once less distinct and much larger. These light-dots, which are constantly visible and uniformly distributed over the whole of the field of vision, governed by movements uniform in character but capable of different directions, are apparently due to the pressure of the blood-current on the smallest structures of the retina, either the constituents of the molecular layers or units of the layer of rods and cones. The units are so small that the pressure image of a blood-corpuscle would cover a number of them, together with the greatly larger intervals between them. It is probable that the visibility of light-dots is largely a question of temperament; nevertheless they appear to be an important factor in the production of optical illusions of motion.

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6. *Optical Illusions of Motion*; *conflicting theories referred to the test of certain hitherto undescribed entoptical phenomena.* *By* BEATRICE LINDSAY, *Girton College, Cambridge.*

The chief examples of optical illusions of motion are the following:—1. *Rectilinear, usually horizontal* illusion of motion, the typical instance of which is the apparent backward movement perceived by passengers in a train which is going through a tunnel; 2. *Centrifugal* illusion of motion, by which stationary objects seem to expand after looking at an object diminishing in the distance; 3. *Rotatory* illusion of motion (Thompson's strobic wheels) by which stationary concentric circles appear to rotate round their common centre.

Two theories have been propounded regarding these illusions, namely (*a*) that they are due to an actual movement of the retina; (*b*) that they arise subjectively by contrast with previous impressions. The latter is the more usually accepted theory; the former is the theory supported, and I think substantiated, by the facts here adduced.

The chief objections to the former theory are as follows:—1. The first illusion is supposed to be sufficiently accounted for by the opposite rush of negative images described by Brewster as occurring when a train of moving images suddenly ceases. To this it may be replied that these negative images only occur when the eye is fatigued and not in its normal condition; furthermore, the opposite direction of the rush of negative images requires in itself to be accounted for. 2. With regard to the centrifugal illusion, it is supposed impossible for the retina to move in all directions at the same time, so as to produce an 'all-round' illusion. To this it may be replied that a very complex curve of illusion can be produced by

known methods, and that the union of both eyes to accomplish similar but opposite curves would produce this 'all-round' illusion. 3. With regard to the rotatory illusion, it is contended that no proof can be given of the existence of a movement in the eye. To this it may be replied that when the rotatory illusion is voluntarily induced, pressure images of blood-corpuscles appear, showing that the retina is being subjected to some peculiar muscular strain. 4. The most important objection made to the theory of movement of the retina has been that the optical illusions of motion cannot be voluntarily induced; but, with the exception of the centrifugal illusion, I find that they can, by practice, be so induced.

The voluntary production of optical illusions is dependent on the above described curious entoptical phenomenon, that there is constantly and invariably present to the normal eye, when trained to such observations, a current of small uniform pressure excitations, distinguished as such by their metallic lustre, faint yellow in colour, and of minimal size and brilliancy. This current of minimal points of light, hereafter indicated by the name of 'light-dots,' is, as above stated, apparently to be interpreted as an incessant wave-movement of pressure images, due to the mechanical excitation produced by the circulation of the blood in its passage under or near certain minimal units of the retina, possibly the rods or cones or the peripheral nerve-fibrils respectively connected with each of these.

This interpretation of the current of 'light-dots,' although it appears startling, seems to be warranted by the following data:—1. The minimal size of the dots, a number of which stand in the area which is filled by the pressure image of a blood-corpuscle. 2. Their uniform size and uniform distribution at fixed intervals throughout the circle of distinct vision. 3. The character of the current as a wave of increased brilliancy affecting fixed points, without any movement of the individual dots. 4. The constant and invariable presence of the phenomenon to the trained eye under all circumstances of accommodation, and all circumstances of light and darkness. 5. The uniform normal rate of the movement. 6. Its unmistakable increase of speed, associated with a greater brilliancy of the dots, under circumstances which increase the rate of the pulse, such as mental exertion or excitement, or brisk physical exercise.

By practice the current of 'light-dots' can be made to move in any direction desired. When the current is watched or altered its speed increases, *a movement of the retina, probably in the direction of the movement observed, being thereby indicated.* In the *fovea centralis* the 'light-dots' seem to go round in circles, indicating the complex circulation in that region, which is apparent from other experiments. The possibility of observing this current in all directions tallies with the theory of its connection with the blood-supply travelling in all directions; its variation in definite lines indicates that, in watching it, a movement of the retina takes place in a definite direction; and the ordinary observation of the current, as possessed of a horizontal movement, is probably governed by the easiest line of movement for the eyeball, viz., in a more or less horizontal direction.

This current of light-dots, with its associated movements of the retina, is shown by experiment to be connected with the conditions of optical illusion in the following way. Four horizontal movements of the current may be distinguished, and, after some practice, induced at will, by movements which are not apparent to consciousness otherwise than as a vague sense of effort: namely (1 and 2), movement respectively to the right or to the left at a normal rate; these are conditions of the still and resting eye; (3) a movement at the increased speed which indicates some movement of the retina in the direction of a moving train of objects; this is the condition of the eye watching the landscape from a moving railway-carriage; (4) a movement, at the same increased speed, in the opposite direction from the moving train of objects; this condition of the eye, when induced involuntarily by the sudden removal of the train of objects watched, produces an illusion of sudden backward movement, as in the case of the familiar illusion given when a train passes through a tunnel. The same illusion may be induced voluntarily in a tunnel or in travelling by night, and either can be voluntarily removed by the reverse movement of the eye. This fourth condition of the eye, when voluntarily induced by daylight, produces an apparent extra speed of the

train, blurring objects even when the train is slow. By the voluntary choice of direction and speed for the current of 'light-dots' many similar illusions may be determined—*e.g.*, the apparent hastening of the moon or stars through clouds, the apparent stationary position, notwithstanding its vibration, of a train in the dark, or on one's waking up from sleep; the speed of a passing train attributed to a train at rest, &c. In brief, *the apparent movement voluntarily determined for the current of light-dots determines, modifies, or destroys, according to its relative direction, the occurrence of these illusions.*

The centrifugal illusion appears to be similarly induced by a more complex movement of the retina; the rotatory, by watching the circling currents of the *fovea centralis.* Involuntary continuation of the curved line of movement induced by watching water makes flat surfaces appear to move in wavy lines. Reflex reversal of the current, after long-continued reversal of the direction of moving objects, as at sea, tends to repeat itself when the cause is past, producing by coincidence with respiration, viz., of an upward movement with expiration, and a downward movement with inspiration, the sensation of going down and up in a boat—an illusion commonly experienced after a sea-voyage.

It must be added that this and other optical illusions are probably to be regarded, not as independent and purely optical phenomena, but as belonging to a complex set of sensations, initiating, in voluntary illusion, or following upon, in pathological illusion, those sub-conscious sensations connected with the ear which are associated with the balance of the body in its various positions.

7. *The demonstration of a new Myographion.* *By* Professor McKendrick.

8. *A new Physiological Principle for the Formation of Natural Bodies.* *By* Professor Jessen.

9. *A new Geometry for the Bodies of Man and Animals.* *By* Professor Jessen.

10. *Further supplementary remarks on Supposed Cycloidal Rotation of Arterial Red Discs.*[1] *By* Surgeon-Major R. W. Woollcombe.

The author suggests that the difficulty of finding with a microscope in bodies so small and symmetrical the existence of cycloidal rotation may be lessened by the attention of the observer being less directed to the rotation itself than to some of its consequences; thus, even in a gyroscopic disc of four inches it is not always easy to say, even when rotation is rapid, whether there is rotation or not; but when an attempt is made to impart rotation about a second axis of the disc, then that about the first or shortest diameter is at once declared by the resulting precessional movement or tendency to rotate about a third axis intermediate to the other two; so, by examining an artery that is not straight but spiral, a precessional movement in the discs may be found there (?) caused by the spirality of the artery superimposing a tendency to a rotation about a long diameter on the (assumed) previously existing cycloidal rotation about the disc's shortest diameter, and such a compound movement towards a third axis may become visible when the ordinary rotation (as within a straight artery) might not. Secondly, in the latter the mode of travelling of discs would be more orderly than if there were no regular rotation, as the planes of rotation would, by the rotation, be more or less fixed, and thus be more parallel to one another than if the discs were devoid of rotation about their shortest diameter. Thirdly, it might be possible for a skilled manipulator in such

[1] Continued from the *British Association Reports* for 1881 and 1886.

inquiries to impart a lateral impulse to discs, so that a precessional movement might become visible when the simple rotation was not so.

To have been translated without rotation, a body, such as an arterial disc, must have been subjected either to a force passing solely through its centre of gravity—to suppose which is absurd—or it must have been subjected to forces (also in its line of projection) about its centre of gravity and on either side of its line of motion *strictly equal and parallel to one another,* the which, in the presence of the fact that the arteries are so largely curved—a condition necessitating unbalanced impulses—seems to the author equally an impossibility.

Any other direction of impulse during translation necessitates also rotation; thus impingement on the side of the vessel is a tangential force not passing through the centre of gravity of the disc, and such would give rotation; also the other tangential force described in the volume for 1881 of the British Association Report by the author as evidenced by the experiment of Dr. Plateau with a rotating globule of oil. Both this cause of rotation and that just before mentioned are in harmony with the natural law above referred to; and when to these causes of rotation is superadded the fact of the very oblate form of the disc, coupled with the important nature of the functions assumed to be by such means fulfilled, the author cannot but believe that the cycloidal rotation of arterial discs would long since have been manifested by the microscope but for the extreme difficulty and delicacy attending its recognition.

Section E.—GEOGRAPHY.

President of the Section—Colonel Sir Charles Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.

THURSDAY, SEPTEMBER 1.

The President delivered the following Address:—

'The geographer should therefore chiefly devote himself to what is practically important.'—Strabo, c. i. § 19.

My predecessors in former years have used their discretion in the opening address either to generalise on the science of geography or to lay stress upon those particular subjects to which they considered it desirable to call attention. I propose on this occasion to refer to matters which have long been of importance to those who are desirous of the spread of the knowledge of geography, and in which I trust the public generally are acquiring an interest. I refer to the teaching of geography in our schools and the economy and advantage to the State which would result from a more perfect and skilful system of instruction.

The term geography covers a very wide area, and while limiting its use to-day to the more restricted sense generally accorded to it in modern times, I must protest against its being applied only to a dry digest of names of places and record of statistics, rendering it a bugbear in the instruction of youth instead of allowing it to cover all those interesting and engrossing subjects which truly belong to it, and without the knowledge of which the mind of youth cannot be trained and expanded in the direction to which the science tends.

As the geographer Strabo points out, our science embraces astronomy, natural history, and is closely connected with meteorology and geometry, the arts, history, and fable; but since his day so much progress has been made in the arts and sciences that the branches of geography have become specialities to be taught separately, and the old root geography has been almost laid aside and treated with contempt, though it is only by a thorough acquaintance with it, the knowledge of common things, that the branches which depend upon it can be thoroughly comprehended. We may take geography, then, to embrace all that knowledge of common things connected with the surface of the earth, including the seas and the atmosphere, which it is necessary for every human being to be acquainted with in order that progress in other knowledge may be acquired and acquaintance with the world be made which will fit man for life in any capacity, whether as occupying the highest position even to the most humble. Indeed, it is difficult to say in what capacity in life this knowledge is most required. No man can do practical work without it, and to the theorist it is absolutely essential.

The science may be divided under two heads: that which we learn from others, that which we acquire from our own observation and researches. All experience tells us that the information is most valuable which we acquire by our own exertion, and therefore every effort should be made by those interested in the welfare of mankind to endeavour that each one should learn everything that can be learned from his ownobservation properly directed.

Year by year, as the surface of the earth becomes better known, the districts in

which explorations of an adventurous nature can be made diminish more and more, and as scientific research takes the place of that of a ruder nature the chances of excitement grow perceptibly less. Indeed, when we look upon the knowledge possessed by the ancients and study their cosmogony we cannot but feel the loss we have sustained in approaching the truth. The poetic halo with which everything was encircled, the deep shadows and gloom, have gradually been dispersed and dispelled, together with all the distant and uncertain light which gave so much scope to the imagination, and we now view the hard stern realities of fact, brilliant and gay in their colouring, but leaving no room for fancy, or for a change of ideas—always the same vivid rigidity of outline which admits of no two opinions. It is like the change of scenery from our own beautiful cloudy island, where the tints and shades change from hour to hour, and where the grey and purple distances leave so much to the imagination, to the bright scenes of the Mediterranean shores, where everything is bathed in intense sunlight, and distinctness of outline reigns supreme, where there is no possibility as to doubt.

In each case we may balance the advantages and disadvantages; but as we have gained in knowledge so we are losing in understanding. We are fast losing our human nature and are becoming machines, and we call it being civilised. We are drifting into a condition in which we learn nothing of ourselves or by our own individual efforts; we are coming to a time when, as we know more about science, and are better educated in arts, we know less about mankind, and are the less able to assist in gaining knowledge for the world; all power of doing so is day by day becoming vested in the hands of a few scientific men, on whose word we have to rely. In this progress we are losing all we used to hold most dear; the desire of living for others is departing, and with it hospitality, chivalry, enthusiasm, unselfishness, and because we are unable to exercise the talents given to us they rust and corrode. No doubt we are able to seek other channels for our energies of mind, but how are we to exert our physical powers for the benefit of man? In days of yore it was open to any man of spirit and strength and activity to set out in quest of adventures of the unknown for the assistance of his fellow-men, to relieve the world of its monsters, to risk everything for others. But those days of daring are now gone by; the doubt, uncertainty, and mystery attached to unknown danger are no longer to be met with, and though the same chances are always presented to human nature to practise self-denial, they are now, though more difficult perhaps, of a passive instead of an active nature, and do not so distinctly belong to the domain of geography as they did in olden times.

As the people of olden times are to those of the present day, so may we consider the child to the man; and we adults in this assembly must recollect that, however strong may be our emotions and passions at the present time, they are but of a mild and vapid nature when compared with the aspirations and feelings of youth. Each prosaic-looking child is full of poetic and romantic feeling, to which as a rule utterance is never given, but which, nevertheless, cannot be rudely shattered without injury to the mind, and which, if taken advantage of, may assist greatly in training the mind and developing a love of geography.

It should be a matter of great interest to those who instruct in geography to study its gradual development from the earliest date and to watch the progress it has made. And this is not a matter of very great difficulty, for as geography is the knowledge of common things, and the ancients were more experienced observers than ever we may hope to be, the earliest records we possess are full of geographical accounts. In the books of Moses, three thousand years ago, we obtain our first recorded view of the cosmogony of the ancients, at which time the world is supposed to be a flat disc with water surrounding the land, and this idea pervades later books, and is dwelt upon in the Psalms of David. Homer also held a similar view, and to him is accorded by Strabo the honour of being the founder of geographical science, because he excelled in the sublimity of his poetry and his experience of social life; and a reason why he excelled is carefully related. He could not have accomplished it had he not exerted himself to become not only acquainted with historical facts, but also with the various regions of the inhabited land and sea, some intimately, others in a more general manner. 'For otherwise

he would not have reached the utmost limits of the earth, traversing it in his imagination.' Herodotus, to whom we are indebted for furnishing us with the *earliest known* system of geography, also held the same view concerning the earth; but it is worthy of remark that he speaks in his day (450 B.C.) of there being another view, as to the world being round, which he considers to be exceedingly ridiculous, and therefore it may be surmised that even at that early period there were minds that had arrived generally at the conclusion which now obtains as to the shape of the world. The idea that the sun, moon, stars, and planets revolved round the earth was the view in early days, and continued up to quite a recent period, and even now we are unable to prove that the generally received system is correct, and only use it as being more convenient than that which makes the earth the centre of the universe.

When we come, however, to consider the progress of discoveries on the surface of the earth itself, the strides in latter years appear to be enormous, but yet we must not forget that there is an ebb and flow constantly going on. Discoveries are made and lost sight of, and again are brought forward as new. Sometimes after an account of discoveries has been published a second account differs most materially from the first, and the public have to wait for further examination. Cases have occurred, as in the early Portuguese discoveries in Central Africa, in which the plans and accounts have been laid on one side and forgotten, and the territories rediscovered and surveyed years afterwards. Again, sketches of new countries have been made, and the surveyor has omitted to show what is conjecture and what is from actual observation, and his plans throughout have been discredited. In some cases these mistakes have retarded discovery, in some they have directly led up to it—as, for example, in the gigantic geographical error in placing on the globes of the fifteenth century the eastern extremity of Asia no less than 150 degrees of longitude too far east, which prompted Columbus to endeavour to reach Asia from the west, and thus led to his discovery of America.

In gauging the progress of our knowledge of geography we must not, however, simply take into account what has been made by ourselves, but by the known world generally; for example, although the Portuguese circumnavigated the Cape and proved that it was practicable to do so, it is still a moot question whether they were attempting what was known or unknown. At any rate it seems certain that in the thirteenth century—not to go back earlier—the Arabians were aware of the fact that Africa on the south was surrounded by the ocean, and the geography of Abulfeda clearly points this out.

It is, then, a difficult matter to decide what is a discovery in geography. We may possess an exact description of a town and know its position, and yet it may never have been visited by a traveller from what we term civilised Europe.

What we require, however, is precise and accurate information of the earth's surface, however it may be obtained, and to train the minds of our youth in the power of observation sufficient to enable them to obtain this information; and if in so doing our countrymen continue to be stimulated to deeds of daring, to enterprise and adventures, to self-denial and hardships, it will assist in preserving the manhood of our country, which is more and more endangered year by year in consequence of our endeavour to keep peace within our borders and to stave off strife with our neighbours.

Probably many of us here to-day of mature age, on looking back at our early acquaintance with geography, will recollect little but a confused list of proper names and statistics, learnt by rote, and only imperfectly carried in the mind, so that only a few portions stand out still visible, and those probably connected with pleasurable and, in some cases, painful accessories; perhaps those particular lessons which we may have assisted some school friend to master still remain as clear as ever; or, again, those learnt under the terror of the rod.

Taking schools and subjects all round, nothing probably has ever been worse taught than geography was only a few years ago, and very little progress towards a good system has even yet been introduced into higher class schools, though in the schools of the people an effort has been made to render the subject more palatable and instructive.

The faults, however, of the system hitherto in use are now fully recognised, and objections are general that the study has been made too painful a grind and that the whole process has been of too severe a character. If this were the only fault to be found in the old method, I for one would be inclined to adhere to it, assured, as I am, that no training of the mind can take place without great denial and sacrifice in learning self-control. But the real question is as to the practical results of the old system. Are they of such a character with all or the majority of minds (of all classes and conditions) that they have become stored with useful knowledge and at the same time trained to take a pleasure in increasing it in the future? If the results are short of this we cannot but pronounce the old system to be a failure, as the knowledge of geography is the knowledge of common things inseparably connected with the life of each one of us, and there is no better medium through which the mind can be trained to be always in a condition for acquiring knowledge without making too great an effort.

Unfortunately for the prospects of introducing a complete and perfect system ot teaching geography (suitable to most minds), the reaction that has set in recently is likely to lead to evil results if not carefully curbed. It seems now to be desired to promote the acquirement of knowledge at the earliest age without effort and without hard work; but this appears to be directed towards alleviating the toils of the instructor as much as the instructed, and we have now, as a result, children taught common things without any effort to strengthen their memories, and then a system of cramming introduced at a later period, when the memory has ceased to be capable of responding to the efforts made, and consequently all the information crammed in is dropped again in a few months.

The memory of youth is like a cup swinging freely on a pin thrust horizontally through its sides. If the pin is below a certain line, the cup will tilt over and lose its contents when filled up beyond a given level; but if the pin is near the upper edge the cup can be filled with more and more security. By careful training in the earliest years the cup may be constantly kept full in later years; but by the training at present in use the cup tilts over far too soon.

It seems to me that the remedy recently adopted is worse than the disease it was to eradicate, and that however injurious it was to attempt to store the mind with mere names, yet the memory was trained thereby to retain something definite; and it is still worse to attempt to store the mind with mere ideas without the connection of names, and leave the memory to rust.

There is obviously a middle course which may rid us of the errors of the past without leading us into still greater difficulties. And if we keep the object to be gained always in view, we cannot fail to take a direct line. We want first to lead the memory to constant exertion of such a nature that it grows stronger day by day, but is not overstrained or wearied; at the same time it must be stored with useful facts, which may be quite above the capacity of the mind to comprehend at the time, but which will be required all through life: this can readily be done by means of verses or rhymes set to simple airs and committed to memory by song. There are facts of the greatest importance which can be learnt in this manner with very little effort, and which, if not fixed in the mind at a very early age, the want of them may be felt throughout life; as, for example, the directions in which latitude and longitude are reckoned, in which the sun rises and sets, the relations of the east and west respectively to the north and south, and many other matters which appear to be of a trivial character, but which require to be as rigidly committed to memory by rote as does the multiplication table.

These very small matters are the foundations of everything we require to know, and if we do not have these foundations firmly and securely fixed, we shall be the sufferers all our lives. Too much attention cannot be paid to them, as it is the early lessons which remain most clearly fixed in our minds.

A point connected with this subject, which admits of much discussion, is as to *how* such verses should be learnt, whether with the assistance of books, pictures, or metaphor. Should they come to the memory through the eye, or the ear, or through both? As a beginning, I think that geography should not be learnt from books, but from the teacher, who may use diagrams and pictures, but at the same

time text-books should not be done away with, as is so constantly advocated; on the contrary, they should be adhered to most rigidly. There are few teachers who could improve on a good text-book, but these books should be for the teachers, and not for the children. But the teacher should not use the text-book while teaching.

Children have a remarkable capacity for making pictures for their mind's eye of everything they think of, which is dulled gradually as books are taken into use. This faculty, if made right use of, may be developed, and will greatly assist the study of geography, and will lead to a 'picture memory,' which will be most useful in regard to maps, drawing, and spelling. This faculty can, of course, be over-cultivated, but there is not the remotest danger of this occurring at present in any of our schools. When highly developed, we find it employed by novelists, who can bring their characters up before them and picture them enacting their parts, and also by artists, who sometimes lose the power of discriminating between that which they actually see and that which their picture-memories call up.

Although it seems to me absolutely essential to cultivate and develop the memory, so often called the 'parrot memory,' of young children, this is by no means all that is necessary. At the same time must be taught the proper use of the powers of observation with reference to nature, which in towns is so difficult a matter, placing the bulk of our population at so great a disadvantage. One of the first points neglected by teachers generally is to explain to children what the object or result of the lesson is to be. In most minds it is very difficult to pay real attention unless it is known what is to be the general drift of the conversation, for otherwise the mind will be directed to points quite irrelevant. Children should be first told in a few words the line the lesson is going to take; this will greatly tend to secure the attention of what are termed dull children, who often, if properly treated, would turn out the cleverest, but who cannot grasp a subject until they see it from all sides, and know it thoroughly, while the 'clever children' are satisfied with a view of one side only. The foundation should be laid slowly, the progress being governed by that of the 'dull children,' who often will most amply repay the teaching. The clever child will not be hurt by having the subject impressed upon his mind over and over again, so long as it is made interesting.

Great care must be taken in the method of presenting maps at an early age before children, and a distinct idea should be given of the difference between a map and a picture.

It must be recollected that from the moment geography is taught, children will make maps or pictures in their mind's eye, whether they are actually presented to them or not.

For example, if a house or a garden is mentioned, both the teacher and the child must view it from the outside and from a certain distance, for it is impracticable for most minds to look all round and behind at one time. To have a full view of what is mentioned it is necessary to get outside and beyond it. Children will differ among themselves in their method of viewing what is spoken of, but the teacher can readily ascertain what mental pictures they have formed, and can make use of this faculty in the first use of maps. Children should first be instructed in maps of the village or town in which they live. It is remarkable how readily uneducated natives in uncivilised countries can understand plans from their constant observation of nature. Most intelligent Bedouins are able to make a rough plan or diagram in the sand with a stick of the district they know, and will also take care that the orientation is correct. Kaffirs can do the same, and can point out the direction of a cattle post fifty or sixty miles distant with unerring sagacity.

It is of vital importance that children in our island, who cannot under ordinary circumstances have sufficient opportunities for using, cultivating, and developing their powers of observation to any purpose, should have the use of maps put before them in such a manner that they will not be led into error. Otherwise they will have fixed in their minds factors of discord which the teacher may know nothing of, and which will trouble them through life, and which if they do get rid of with great labour in after-years will constantly return at unseasonable moments.

It is very common for children to mistake east for west, north for south, and even to make still more ridiculous errors which appear on reflection to be quite impossible. Yet these errors remain often unobserved until the youth is eighteen or nineteen years old, when he begins to think the matter out for himself, from finding that he is continually making absurd mistakes, but then it is too late for him to do more than know that he is liable to the error, for on an emergency it will crop up in spite of himself.

I am aware of one instance in which an educated surveyor when thinking of London invariably placed the portions about Regent Street and Charing Cross in an inverted position while picturing all the rest correctly, and it was only by an effort that he could turn this portion upside down into its place. Another, when thinking suddenly of Paris, always placed it to the north of London, and another always thought of the west end of London as being towards the eastern coast.

Out of thirty cases of well-instructed men at an age between eighteen and twenty, I have found that about eighteen were under the impression that while the sun rises in the east, the stars rise in the west, from having learned that the sun has a proper motion among the stars.

I fancy there are few educated men who have not grown up with some curious errors with reference to geographical facts which have bothered them all their lives, and which they have found it impossible to get rid of even when they have discovered where the errors lay, and I believe that many of the numerous blunders and accidents which constantly occur on railways, with shipping, machinery, &c., and the causes of which cannot be accounted for, are really to be ascribed to some early error in learning geography or the knowledge of common things, errors which, when attention and watch over self is suddenly withdrawn, influence the actions in a contrary direction to that which is right.

As an instance of the natural liability to error, even apart from those which may be ingrained while under instruction, I may allude to the feeling when the eyes are shut when travelling by rail or carriage that the vehicle is going in an opposite direction to that in which it actually moves, to the impression when approaching or leaving land in a boat or balloon that the earth is moving and that oneself is stationary; even when on horseback under excessive fatigue in the dark the traveller has been known to imagine that the horse was moving rapidly backwards. The effect of excessive fatigue from physical exertion has somewhat the same result as a want of self-control from bad training of the mind, and perhaps those who have ridden for many hours on horseback or in a coach may have noticed how in the dark a fixed lamp may be seen to make various fantastic signals due to the motion of the horse or coach transferred by the eye to the lamp. As another instance of the difficulty of self-control I may mention a case in which a man well instructed in taking astronomical observations and in the rudiments of astronomy could not divest himself of the idea, which he had gained as a child, that the moon shines with light of her own, and that her phases are due to the earth getting between her and the sun, this error continually interfering with his mental astronomical pictures, though when his attention was specially called to the subject he was aware of the error which intruded itself so constantly in his views of the heavenly bodies. The difficulties regarding east and west, north and south probably arise from a multiplicity of causes, such as the southern side of the Mediterranean being the northern coast of Africa, or the southern view of a house being obtained by looking towards it in a northerly direction, and these difficulties as to orientation do not only occur in modern times, but are to be found in ancient writings. Another constant source of error is inverting names unconsciously, such as speaking of Jupiter's rings and Saturn's belts. As an instance of this I mention a case in which, a lecture being given on the Franco-Prussian War, the lecturer inadvertently in the middle of his lecture used the word 'Prussian' for 'French,' and *vice versâ* continually throughout, and though he was quite aware of some anomaly every now and then, he could not ascertain where he was in error until near the end of his lecture. Another source of error which cannot be too carefully guarded against results from placing the celestial globe by the side of the terrestrial

globe and treating them as though they are of the same character; this is certain to confuse east and west with most children, as one has to be looked at from the outside and the other from the inside in actual fact. Again, as some star charts are so made that they may be looked at from above and others from below, causing the east and west points to differ, there is sure to arise confusion. I venture to say that there are few young minds which are not absolutely and hopelessly confused by the use of celestial globes and charts. I believe it to be essential that until the mind is fully trained and developed the stars should be looked at from within and not from without, and it appears to me that all the information which a child can require, apart from practical observation, concerning the phenomena of day and night, the seasons and months, the circles and zones, the phases of the moon and eclipses, can be imparted by the use of a lamp with a reflector and two globes, though a good orrery placed in the school for children to examine and observe for themselves would often enable the dull ones to keep up with the rest more easily.

It will be interesting to note whether the class of error alluded to does not arise principally among those bred in towns, and who have not had an opportunity of developing their observation in the country; as with those who do use their observation a habit is acquired of unconsciously working out questions which arise, and the mind arrives at a correct conclusion. This end should be the great aim and object in instructing in geography, for as there is no royal road to knowledge divested of grind and pain, there is yet the path which provides the greatest amount of result with the least amount of grind, in which all the labour expended is productive, and in which after a time labour even becomes a pleasure.

It seems very desirable that the first maps presented to a child, viz., those of the school grounds and the parish, should be placed on the floor and properly oriented; this will go far to fix the correct positions of east and west, north and south, and will prevent the idea of the north necessarily being *up* and the south *down*. It is to be observed that if the child looks up to a map it is almost equivalent to looking at the map when lying on the back, in which case the east and west are inverted. The motion of the sun over the map might with advantage be pointed out at various times of the day, and if the position of the rays of the sun on the floor when on the meridian could be shown each day when practicable on the line drawn north and south, it would do much to fix in the mind the fact that the sun is in the meridian at apparent noon each day. A sundial should also be available in every school-yard to which children may have access.

The map of the district round the school should only be made use of in order to clear the way to understand what a map is, for reference in describing other maps and for practical purposes in giving the child useful information as to the places in the neighbourhood. While this is going on the child should be taught to point out the actual directions in space of the principal towns, &c., in the county and island, and then an outline map of the British Isles with the principal places and features marked on it should be brought under review. Too much detail should not be crammed into the early lessons; a good firm foundation is required, something to start upon before the great test of faith is made in teaching, viz. that the world is round.

Children should be taught, as far as is practicable, to make this discovery for themselves, and many will arrive at it one way or another, or think they do so, which is equally important. It is far better they should grasp truths themselves than have them drummed into them; it gives them confidence in their own deductions and leads to further observation of nature. In introducing the world as round, a *blackboard* globe should be used, about three feet in diameter, on which the continents are outlined boldly in red, with some meridians and parallels of latitude in white. It would be well if a portion of this globe could be taken to pieces to show how a horizontal sundial for the particular latitude is constructed, and for other matters of interest. It is material to show that the earth revolves on a fixed axis from day to day, and in one direction. All the great difficulties in learning geography are at the threshold of the science for those who have not observed nature; the more abstruse subjects are comparatively easy to teach.

The first difficulty common to all is that with reference to latitude and longitude,

regarding which there are so many elements of error. It is so difficult for the child to recollect which term means length and which breadth, and then to get the restive imagination to grasp the fact that the length is sideways and not up and down, as it apparently should be; for even if the earth is shown to be an oblate spheroid, there is nothing to lead a child to see that there is a greater circumference round the equator than round the poles, and the time has not arrived to perplex the child with the views of the ancients on the subject. Then, again, if the child does recollect that the meridians of longitude run from north to south, and the parallels of latitude from east to west, it is probable that he may measure the longitude in degrees along the meridian and the latitude along the parallels; a very common and recurring error, difficult to deal with. The only practicable method is to put the facts of the case into amusing verse and commit it to the memory by song. At this stage, also, some easy standards of measurement put into verse and to music should be learnt by rote, to enable the child readily to recollect the relative measurements of the earth, sun, and moon, and the radii of their orbits and times of progression.

I lay great stress upon these matters at the beginning, because they are really all in all to those who wish to succeed in the science in after-life, and I have viewed the matter from the standpoint of what will be required at the age of eighteen to twenty, when the mind ought to be capable of taking up any subject, instead of considering what show of learning the child should be able to produce in an examination at an early age. The stock-in-trade of knowledge for each young person need be very slender, but it must be of the right sort and best quality. No doubt there are many children badly trained who can gradually work out matters correctly for themselves, but these are the few with originality of mind, and even they would be benefited by not having to spend a portion of their lives in unlearning.

Once the preliminary difficulties are over and the power of observation and reflection is acquired, even in a small degree, the study of geography becomes but a simple matter, for it is the learning of common things, matters of everyday life, which we may, if in the country, acquire to a partial extent of our own experience; but though so simple it requires continuous application and attention.

In each calling or trade a man may become an experienced geographer to a limited degree. The pilot, for example, is an expert in the geography of the seas he works in, for he not only knows the ports, the coast lines, and the sunken rocks and sandbanks, but he also knows the tides, the winds, he studies the clouds and the currents, and has an intimate knowledge of the contours of the shallows; moreover, he knows the shipping of various countries, the merchandise they carry, and the produce shipped from each port. In the same manner, by hunting, shooting, fishing, bicycling, birdsnesting, &c., we acquire a knowledge of natural history and topography which aids us most materially in the study of geography, and which in a limited degree *is* the study of geography.

Even in large towns it is practicable to learn lessons in geography from actual experience and observation, for if the markets and railway produce are examined, it can soon be ascertained whence the articles come and from what ports, and with careful attention most valuable lessons in political economy can be gained.

The bulk, however, of our children are cooped up in towns and walled playgrounds, and even when in the country are too often confined to one field; they have few opportunities of insensibly studying the wonders of nature, and therefore in order to develop their powers of observation and to understand geography artificial means must be made use of. Great efforts are now being made under the New Code to produce these artificial means, by raised models and water and other devices, and it is to be hoped that, if these schemes can be carried out, the habit of observation will be induced; but the memory also must be at the same time actively exercised and stored with fresh facts day by day.

The knowledge of geography thus, even in its restricted sense, embraces the life of an Englishman of every class and occupation, and its study is of the greatest importance to every man who has an occupation; it is singular that so little comparatively is thought of cultivating the science, and how small interest the State has hitherto taken in fostering this class of education.

But while the Board and other schools for the people are gradually taking up the work and endeavouring to work out a good system of education, it is mortifying to find how little progress has been made in the higher class schools where such heavy fees are charged; and the question arises whether in these schools the teachers of geography really understand the subject they teach, and would pass an examination before a Government Inspector.

The boys of the wealthy classes are put to the greatest disadvantage with regard to the study of geography. The son of a labourer will hear the price of provisions and clothing constantly discussed, so also with the son of a mechanic and tradesman, and will learn much about geography on the subjects with which the parents are connected, and will also in some measure learn to exercise his observation; but the son of wealthy parents is too often carefully kept from hearing all that might teach him geography, and he is seldom obliged to exert himself to use his observations in any essential matters of daily life; this is reserved for the playground, where nothing of real importance is at stake, and must have the most deleterious and detrimental effect on many young minds, and naturally results in so large a proportion becoming useless for any occupation.

It is apparent that, as education throughout the country progresses, the sons of the wealthy classes, if they are to compete successfully with others, must have some better mental training than they obtain at present, otherwise they will in a few years be distanced by the sons of the labourers, artisans, and shopkeepers. What an Englishman asks for is a fair field and no favour, and it seems hard upon a parent who struggles through life to make money to be enabled to give his children the best and most expensive education the country affords, that with it he must risk a training of the mind which is inferior to that in the less expensive schools of the people. As we are behind the Continental States and our colonies in so many of our institutions and land laws, so we are behind them in our training of the mind in our upper-class schools; by neglecting by artificial means to develop the power of observation among boys, who until they are put out in the world are never accustomed to do anything that will tend directly to any practical and useful result, we are putting them to the greatest disadvantage, and handicapping them in the race of life.

We omit to train the memory in early years, to lay a foundation of facts in the mind, and to develop any power of observation; we carefully prevent their doing anything useful, and bring them up in a moral atmosphere in which the idea of anything but amusement is practically excluded, and then in later years we attempt to adjust all our errors by cramming, when the memory is incapable of being crammed, and the mind has ceased to desire to acquire information; the result is that so many young men are deliberately rendered unfit for work in life, and those who have sufficient courage and energy to look their prospects in the face find the enormous disadvantages to which their teaching has subjected them, and lose precious years in unlearning and learning again.

More unfortunately still, the best and choicest of our minds cannot be crammed; and thus drop out at our examinations many minds of the class that for practical purposes would be most useful to the State. I allude more particularly to the minds endowed with reflective faculties, which tend to originality and research; these minds cannot be successfully trained unless combined with the teaching there is something useful to do. It is often observable that an indolent, inert, and lazy boy suddenly becomes filled with enthusiasm and emulation, both at studies and in the playground, when subjected to a change of training. I venture to assert that every year at our public examinations many men are rejected who are of the most superior class of mind for all practical purposes, who are physically most capable, who are so constituted that they cannot cram, and who, though retarded by want of proper training, are beginning to train their minds for themselves, and who if brought up under a good system in early years would take the highest places in examination. We are thus losing year by year from our front rank the men who would be of the greatest service to the State.

The pleas given for the study of geography by Strabo are worth bringing before the mind of youth, for he points out that while the success resulting from

knowledge in the execution of great undertakings is great, the consequences of ignorance are disastrous, and he refers, among other instances, to the shameful retreat of the fleet of Agamemnon when ravaging Mysia, and to bring it more home to our everyday life he says: 'Even if we descend to such trivial matters as hunting, the case is still the same; for he will be most successful in the chase who is acquainted with the size and nature of the wood, and one familiar with the locality will be the most competent to superintend an encampment, an ambush, or a march.'

He further calls attention to 'the importance of geography in a political view. For the sea and the earth on which we dwell furnish theatres for action; limited, for limited action, vast, for grander deeds; but that which contains them all, and is the scene of the greatest undertakings, constitutes what we term the habitable earth; and they are the greatest generals who, subduing nations and kingdoms under one sceptre and one political administration, have acquired dominion over land and sea. It is clear, then, that geography is essential to all the transactions of the statesman, informing us as it does of the positions of the continents, seas, and oceans of the habitable earth.'

Of all persons who require a knowledge of geography stand first those who are most concerned in the government of our empire, and yet, as has been mentioned, they have for the most part been brought up at schools where the mental training for geography is most defective. Our statesmen as a rule have neither theoretical teaching nor practical experience in the science, and it is perhaps not too much to say that, putting on one side those who are merchants and sailors, there are no more ignorant persons with regard to geography than our law-givers. This ignorance endangers the safety of the country, for the people are continually perceiving, with regard to matters of everyday life and practical experience, that their law-givers are more ignorant than themselves, and are consequently continually interfering and giving advice in the details of the administration of the empire.

The progress and development of a free country depend upon the characteristics of the inhabitants, but these again depend in great measure upon the natural resources of the country—the soil, climate, mineral wealth, navigation, mountain ranges, risks and dangers from natural causes, and we must not omit the position of the country both with reference to commerce and war.

It is not usually the country too greatly favoured by nature which develops most rapidly, neither is it necessarily a long term of peace which favours progress; on the contrary, all experience shows that man requires a certain amount of opposition to bring out his energies and stimulate him to exertion, and though we are constantly talking in our country of the blessings of peace and horrors of war, we must generally acknowledge that our present foremost place among nations is due in a great degree to the keeping up of our innate energies by incessant turmoils and differences of opinion within and little wars and commercial rivalry without. It is not, then, to a reign of peace in which our energies would stagnate and become effete, but to a continuance of political excitement, which keeps the people on the alert, that we should be indebted for progress, and our statesmen should be sufficiently well educated and trained to take advantage of every time of excitement in furthering the welfare of the empire.

We owe the benefit (before railways) in the improvement of our Great Northern Roads for military purposes to the rebellion of 1745, leading to our being able to run coaches between London and Manchester in 1754, and between London and Edinburgh in 1763. Scotland and Ireland are both indebted to war and disorder for the first roads, constructed for purely military purposes.

But while the duty of taking advantage of each fitting opportunity for developing a country lies with the statesman, his prospect of success depends in great measure upon his geographical knowledge. His work may serve but for the purposes of the moment, and never benefit posterity, if he has no knowledge or foresight, no originality of purpose and perception of the fitness of things.

The measures that can be taken may be divided into two classes—domestic and international. The former designed to benefit the country or empire directly; the latter to shield the land from hostilities from without, and in which the

consideration of geographical position has a most all-important bearing. In this latter class a complete knowledge of geography is an absolute necessity, as the question arises so often as to whether the acquisition of geographical positions will weaken or strengthen a kingdom. For example, were Ireland two degrees further to the west, it is probable that all our views as to the method of connecting it for administrative purposes with Great Britain would be greatly modified. Again, the particular points at which our coaling stations may be situated about the world may depend upon a variety of circumstances, changing from year to year. Thus Gibraltar, from its geographical position, was an absolute necessity to us thirty years ago, but, owing to various changes, it is not now of equal value, either as a coaling station, for protecting our commerce, or as a depôt for our wares, and the question is arising with some geographers whether it might not with advantage be exchanged for Ceuta on the opposite coast.

It is possible that a more full geographical knowledge of Egypt and the Suez Canal might have materially modified our present occupation of Egypt. The canal could not be held without a fresh-water supply, and the possession of Cairo and the Nile is the key to the fresh-water canal supplying Ismailia and Suez. Had it been known that a plentiful supply of water could be obtained close to the maritime canal, independent of the Nile water, it is questionable how far any occupation of Egypt would have been necessary.

In such cases it is not sufficient that the Government subordinates should have a knowledge of geography, for even if they are fully conversant with what they ought to know it would be almost impracticable for them to convey to statesmen knowledge which their untrained minds render them incapable of retaining or making use of.

In settling political boundaries it may appear at first sight that they should coincide with certain geographical features, forming natural boundaries not only in international matters, but also in cases of provincial, county, town, and parish boundaries, and also in accordance with historical associations; but we must do our statesmen the justice to admit that the deviations they adopt may not always be the result of ignorance, but arise from an astute perception that it may be necessary in the future to have a cause for further modification, or even for raising the whole question anew. It is difficult, however, to see how this can with any propriety arise in domestic matters, and, apart from the doubtful political morality involved, it would only occur in international matters on the assumption that our empire is paramount, and can quarrel when it chooses; and, moreover, in such a case could only be justified by being carried out with so perfect a knowledge of geography that in any reopening of the question our country should be in the right; whereas bitter experience has shown us that our statesmen have almost invariably placed us in the wrong.

It is fatal in domestic matters to ignore the physical features within a country, and attempt to obliterate its historical and topographical associations, as the French Revolutionists attempted, by substituting their departments for the old provinces. This has only led to an artificial division, which has not taken root among the people, and French geographers are still calling attention to the absurdity of present divisions. In such cases, we must keep alive to what are the ostensible and what the actual reasons for such changes, and if the so-called simplicity introduced by lawyer statesmen leads to increased law expenses, we may reasonably look with suspicion on such an interference with the economical administration of the affairs of the nation. In our own country geography is intimately connected with all kinds of divisions of land, which are dealt with by the administration. A simplification of the arbitrary political divisions, and a modification and synchronisation of boundaries may lead directly to simplification of administrative machinery, and saving of expenses in salaries, &c. London itself is a glaring instance of the waste of money and friction of departments, from the extraordinary overlapping of boundaries—political, magisterial, petty-sessional, police, statistical, postal, public works, &c. Probably a great portion of the time and energies of the superior officers in the various departments is occupied in waging war on one another, keeping the peace, or temporising with or watching each other; and this not from their own

desire to quarrel, but from the fault of the system which overlaps duties as well as boundaries, and often gives one and the same duty to be performed by distinct departments. Perhaps, in some instances, this friction may call out latent energy, but it at least most successfully prevents departmental superiors from looking into their own departmental affairs, and developing and perfecting the local administration, and keeping up to the times.

With regard to international boundaries, too little attention is usually paid to the changes which are caused by the advance of civilisation. For example, a natural boundary may, in time, become merely conventional owing to development of communications.

At one time the Rhine was a natural boundary, but it has now become a channel of communication. Again, the Zambesi is at present a natural boundary, completely separating distinct tribes; the time may come when it also will be a great channel of communication. The usual natural international boundaries are broad or rapid rivers and arms of the sea, mountain ranges, deserts, and swamps; but the highlands and lowlands of a country are also naturally separated, as they usually are inhabited by people of different nationality.

In Europe we find natural boundaries gradually losing their efficiency as political boundaries. The Rhine, for example, throughout a great portion of its length has ceased altogether to be a political boundary, for though it is still a military line of great strength, each large town on either bank has its suburb on the opposite side, and the population has become so assimilated that the river has ceased to be a practical political line. Consequently the line of the Vosges is deemed by many to have become the natural boundary between France and Germany, on account of its coinciding with the linguistic barrier. But, again, linguistic boundaries are no tests of the limits of nationalities or national feeling. When a foreign language is forced upon an unwilling people, they may for many generations be acutely opposed to the nation whose language they have adopted. On the Lower Danube, however, the physical, linguistic, and political divisions all coincide, and the river has become neutralised and is a natural boundary.

In central Europe we find the highlands of the Alps forming the natural and political boundary, though the people speak three different languages; but in these cases the people probably will not be found to be of the same race as those speaking the same language in the plains below.

Again, in the Pyrenees we find a natural, political, and linguistic barrier coinciding, assisted by the fact that the mountain people are a different race from those in the plains to the north and south.

In our own country we have a curious instance of language being no proof of the nationality of the people, as the Iberians in Wales speak Celtic, and the Celts in western Britain speak Anglo-Saxon. Again, in South Africa we have the people of French extraction speaking Dutch and still feeling resentment to the government on account of its having forced a foreign language upon them, although the British have succeeded the Dutch.

Among Asiatic and African territories boundaries are often very ill-defined and uncertain. Frequently it happens that between two powerful states there is a large tract of country which owes a double allegiance, paying tribute to each, and yet in some respects remaining independent, probably consisting of lands which are easily ravaged and are comparatively speaking unprotected by nature.

When we look into the subject of boundaries among pastoral tribes, we find curious anomalies. The land belongs in many instances to the tribe and not to the individual, and cannot be alienated. In the desert of Arabia a tribe in one part will have an interest in the date palms or corn lands of a tribe in another part, and this system is rather fostered than discountenanced, so that when evil befalls an individual in one part he may go and live with his tribal friends elsewhere. It is a knowledge of the intricate connections of these tribes and the topographic divisions of their lands which admits of any control being kept over these warlike people. A mistake arising out of a misunderstanding of this Bedouin system nearly led to a disastrous result in the Egyptian campaign of 1882, owing to an outlying branch

of one of the most powerful tribes in Arabia being supposed to be a petty independent tribe of no consequence.

In many instances the cattle posts of tribes during peace time by mutual consent intermingle and overlap, yet are kept separate and distinct, so that no geographical boundary is practicable; in fact among such people it is the tribe before the territory which is under the control of the chief. Thus it is quite practicable to conceive instances of a tribe living on lands within the area occupied by another tribe and yet governed by its own laws. Many of the difficulties the British have encountered in South Africa have arisen from a complete ignorance of, or wilfully ignoring, the native land laws. Under the tribal system even the chiefs in council have not the power of disposing of any portion of the land they use; it belongs to every individual of the tribe and of the tribal branches and to their children's children. Thus, when a chief gives over his territory it does not follow that he gives over the land for disposal as crown lands, but only the government of the people. It is on this account that the offer of Khama and other chiefs of the Bechuanaland territory was of so great value. They proposed by agreement in council in their respective territories to hand over to Great Britain their territories, keeping for themselves the lands they used, and offering for emigration purposes their vast extents of hunting lands, which are not now of the same value for hunting purposes as they were in former days.

But this proposal has not been accepted, and a parallel of latitude has been proclaimed without consent of the Bechuana chiefs as the northern limit of the British Protectorate, dividing Khama's territory into two parts and cutting a portion of Matabeleland off from Lobongolo's territory; so that the Boers of the Transvaal cannot raid upon the Matabeles without violating the British Protectorate and *vice versâ*, while we have no means of securing its protection. Again the Matabeles when making their annual raid upon Lake Ngami will violate the portion of the State of Khama without the Protectorate, and he, if he wishes to oppose them, must do so from his capital within the Protectorate. This will bring us into conflict with the Matabeles or else will practically deprive Khama of part of his territory.

It is difficult to conceive any arrangement more likely to lead to complications in the future. The Protectorate, based on geographical principles, should extend as far as the Zambesi, taking in all Khama's certain territory and as much of the neutral territory as might be necessary to provide a natural boundary to east and west.

In East Africa, again, the definition of spheres of action recently is anomalous. A boundary ten miles from the coast for the Zanzibar dominions can of course have only a tentative character, and the exact definition in the future cannot fail to lead to conflicts. Far worse, however, is the adoption of the river Tana as the northern boundary of the British sphere of influence—a river occupied on both banks by the same agricultural tribes. It is not clear for what reason the commissioners have left this difficulty for the future.

It would not be difficult to give many recent instances in which those charged with diplomatic definitions of international boundaries have failed in their duty owing to a want of geographical knowledge of the localities with which they had to deal.

For example, the boundary treaty of 1783 with the United States was incapable of being carried into effect, as the geographical features did not correspond with the assumption of the commissioners. This led to a dispute lasting thirty years, resulting in the boundary treaty of August 9, 1843. The ignorance of the geography of the country in this case led to very inconvenient and even disastrous results.

Again with the San Juan controversy. Historical and geographical knowledge and ordinary care for the future development of Canada might have led to such measures having been taken in the first instance as would have prevented cession of valuable positions to the United States in 1846.

In India, again, our want of knowledge of the country to the north of the Afghan boundary has led to a series of unnecessary concessions to Russia. Had the

slightest encouragement been given in former years by the Indian Government to enable officers to acquire information as to the territories beyond our Indian Empire, no doubt we should now be in a more secure position.

But, fortunately for the British Empire, foreign politicians have also much to answer for to their respective countries on account of their ignorance of geography.

For many years past Germany has been increasing the population of the United States and our own colonies without assisting to further the influence of the German Empire; whereas had her statesmen been able to look forward, a German colony might have been established. Many Germans as far back as 1866 were desirous of establishing a colony in the Transvaal. But Germany now has to cast about for unoccupied territory, and has chosen a piece of useless territory on the western coast of South Africa, whereas with a little foresight Prince Bismarck might have obtained on easy terms the whole of the French colonies in the Gulf of Guinea and north of the Congo, which France had actually abandoned as worthless. Germany would thus probably have held the position of France with reference to the reversion of the Congo State.

By the treaty of Frankfort it was intended that all German-speaking villages were to be ceded to Germany, but the boundary as originally laid down, for want of geographical knowledge on the part of German employés, left several German villages near Metz in possession of France, and it was necessary subsequently to rectify the error.

As a section of the British Association we are interested in the development of geographical knowledge in the world generally, but more particularly in our own empire, and it is only by unceasingly calling attention to our shortcomings with regard to the science which causes us to meet here to-day that we may hope for that progress to be made which will enable us to maintain the proud position we at present hold among nations, owing to our practical skill and energy. Hitherto we have possessed so many other advantages that we have been able to dispense with a good system of instruction, but owing to many causes other nations are gaining upon us in various ways, and we in our turn should use every effort to successfully grapple with a subject which if properly taught must affect our welfare as a nation so deeply.

The following Papers were read:—

1. *Explorations on the Upper Kasai and Sankuru.*[1] *By* Dr. LUDWIG WOLF.

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2. *The Bangala, a Tribe on the Upper Congo.*[2] *By* Captain COQUILHAT.

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3. *The Congo below Stanley Pool.* *By* Lieutenant LE MARINEL.

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4. *Notice sur l'Etat indépendant du Congo.* *By* M. VAN EETVELDE.

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5. *The Lower Congo: a Sociological Study.* *By* R. C. PHILLIPS.

The author deals with the Congo up to Vivi, and with the coast between Loango and Kinsembo. Among the factors which account for the present system of society in this region, climate, similarity of soil, crops, food-stuffs, and the impenetrability of the country, have proved great impediments to progress. The uncertainty of the rains has a disturbing influence upon crops, whilst the ravages of insects and mould render the storage of reserve supplies impracticable. The physical

[1] Published *in extenso* in the *Proceedings of the Royal Geographical Society.*
[2] Published *in extenso* in the *Journal of the Manchester Geographical Society.*

features of the country render the establishment of a strong central government exceedingly difficult, if not impossible.

Physically the natives have probably degenerated from a higher standard. Their emotional nature exhibits a manifest inferiority. They are impulsive, easily roused to laughter, and quarrelsome. Old customs are slavishly followed. The sentiment of public justice is, however, very highly developed. The intellectual development is stunted. All but the more patent and mechanical cases are beyond the grasp of the native, and little progress is made after adolescence is reached. Misfortune is generally attributed to the ill-will of a *ndochi* (wizard or witch) whose detection and punishment is aimed at by the prison ordeal, and whose evil influence it is sought to counteract by charms. The foundation of the social system is the family, consisting of the chief, his wives, children, dependents, and slaves, and marriages between families are much practised. Marriages between blood relations are, however, prohibited. White men are admitted as residents on payment of 'black mail' to the neighbouring chiefs.

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6. *A Visit to Diogo Cão's 'Padrão' at the Mouth of the Congo.* *By* R. E. Dennett.

In April 1887 the author visited the supposed fragments of Diogo Cão's 'Padraõ' or pillar, immediately after their discovery by Baron Schwerin and Senhor F. J. de França. Landing on the inner side of Shark's Point the author came past King George's 'Palace' and the old English cemetery (now submerged), and on some neighbouring high ground he found the remains of the pillar sought for. They consisted of a square base, 27 inches high, a fragment of the pillar, and two ball-shaped pieces of stone, all in white marble. (There can be no doubt that these fragments are identical with the fragments visited by Sir Richard Burton in 1863, and described by him in 'Gorilla Land,' ii. p. 71.—E. G. R.)

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7. *On Acclimatisation.*[1] *By* Dr. A. Oppler.

FRIDAY, SEPTEMBER 2.

The following Papers and Report were read:—

1. *The Raïan Moeris.* *By* Cope Whitehouse, *M.A.*[1]

The Raïan basin is a depression to the south and west of the Fayoum, between lat. 28° 40′ and lat. 29° 30′. Its northern extremity is nearly on a line with Beni-Suef, 73 miles south of Cairo. It is connected on the south-east with a narrow valley, hitherto unexplored, known as the Wadi Muélah. At previous meetings of the British Association it has been shown how the author of this paper was led to believe that some such depression must exist, and how, at first alone and subsequently accompanied by competent engineers, his observations were verified. It was his opinion that foreign engineers, about the fifteenth century before our era, had conceived a gigantic scheme for the regulation of the flow of the Nile and the redemption of the Delta, utilising a depression in the desert as a storage reservoir, to avert the excessive rise of the river and to provide for the season of drought. In Lower Egypt there are three seasons. From April 1 to the end of July the discharge of the Nile is about 14,000 cubic feet per second, or an average of about fifty million cubic metres per diem. A very high Nile discharges 387,000 cubic feet per second, averaging 1,000 million cubic metres per diem. Only about one-half of the Delta, 2,750,000 acres, is under cultivation, for want of sufficient water. In the province of Gharbieh alone the area of land

[1] Published in the *Proceedings of the Royal Geographical Society.*

capable of being reclaimed is reported by Mr. William Willcocks to be over 600,000 acres. Ten shillings an acre is the tax paid by inferior land in Egypt. If the summer supply in the Nile were sufficient for the irrigation of all the land, 2,530,000 acres could be reclaimed. The Egyptian Government requested the author in December 1886 to carry outfurther surveys and detailed engineers to work under his direction. A line of levels was run from Mazurah on the Canal of Joseph (Bahr Jusuf), 26 kilometres to the west. At the tenth kilometre the desert is 54 metres above the Nile valley; at the fifteenth, 154 metres; at the twenty-fourth, 131 metres, and at the twenty-sixth the Wadi Muélah is about 2 metres below high Nile at Beni-Suef (photographs shown). This line was continued to the N.W. into the Wadi Raïan, down to the level of the sea. It was checked by a line to the S.E. and E. back to the Bahr Jusuf. A third line of levels was run between the Gharaq and the Raïan basins, which showed that at the level of high Nile (ca. 30 metres) these two basins are connected by a narrow defile. Another, and fourth, independent line of levels was carried from the west end of the Birket el-Qerun, whose surface level had been previously established as − 40 metres, or 70 metres (ca. 225 feet) below high Nile. Major Surtees, detailed by the War Office, at the request of Sir C. Scott-Moncrieff, to accompany the author, draughted a map with contours which give the following data for so much of the depression as is below the Nile and available as a storage reservoir. Surface at + 30 metres (above sea), 1,100 million square metres: average depth, nearly 30 metres; contents, 31,000 million cubic metres. Major Western, R.E., Director-General of Works, having been directed to examine the whole project, prepared an elaborate and most valuable report, showing that a further supply of 25 million cubic metres per diem for 100 days would meet all the requirements of Lower Egypt. This could be effected by filling the Raïan basin at the time of high Nile, closing the canal of supply until the end of January, when the difference between the water in the reservoir and the river (about 5 metres) would permit a sufficient amount to flow back by the same canal. Al objections, such as evaporation, leakage, deposit, infiltration, impregnation, loss ol head were considered, and shown to be of no serious importance. The project i pronounced by the highest authority in all respects feasible. It is estimated that less than 1,000,000*l.* would suffice for the works, which would consist of a canal across the Nile valley near Feshn, the improvement of the Bahr Jusuf, an embankment and basins in the Nile valley, a cut or tunnel of less than three miles between the Nile valley and the Gharaq basin, an embankment of twenty miles to guide the water into the Raïan basin, with incidental expenses for gates, bridges, &c. It is estimated that the revenue would amount to about two millions sterling, and the cost of maintenance would be inconsiderable. These researches, therefore, represent a capital value of, say, 50,000,000*l.*, and are believed to be unique if regard is had to the historical, archæological, and geographical results as well as to the purely practical question of the relief which would be afforded by an addition of more than one-third to the available resources of Egypt.

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2. *The Feasibility of the Raïan Reservoir. By* Colonel Ardagh, *R.E., C.B.*

Having maintained a constant interest in the investigations of Mr. Cope Whitehouse, and having accompanied him into the Raïan Basin, the author offers the testimony of an impartial observer. Mr. Cope Whitehouse merits the thanks alike of antiquarians as of modern engineers for his researches relative to Lake Mœris. He has discovered a basin or depression, which is undeniably capable of being turned into a storage reservoir, fulfilling all the purposes of the ancient Lake Mœris at a comparatively moderate cost, and has shown that the financial result to Egypt of the construction of such a storage reservoir, capable of supplementing the insufficient quantity of water furnished by the Nile during the period of low Nile, and of thus enabling larger tracts of land to be kept in cultivation, would represent a very large profit on the capital invested, and a permanent increase in the produce of the country.

3. *The Desert from Dahshur to Ain Raïan.*[1] *By* Captain Conyers Surtees.

Captain Surtees, having been detailed at the request of the Department of Public Works to accompany Mr. Cope Whitehouse, draughted a map with contours of the Fayum and Raïan depressions, a copy of which was shown and explained in detail.

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4. *The Bahr Yusuf.*[1] *By* Captain R. H. Brown, *R.E.*

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5. *Between the Nile and the Red Sea.* *By* E. A. Floyer.

The mountainous country between the Nile and the Red Sea partakes of much of the interest, religious, commercial, and antiquarian, which so long has centred in Egypt itself.

Long before the Christian era its mountain solitudes and picturesque valleys attracted the ophthoi, or the monks of paganism. At a later period these mountains sheltered the first Christian monks, and the existing monasteries of St. Anthony and St. Paul carry us back to this early age. A hundred miles to the south of them are the ruins of the monastery of the 'Deaf Men,' and near it, in the beautiful Kittar valley, near a crystal pool of water, and by the side of a running stream, rise the ruins of a Catholic church, perhaps consecrated by Meletius, the Arian bishop of the Thebaid, in the year 300. To the monks succeeded the convicts of the Roman empire, who worked in the granite quarries of Mons Claudianus. For 1,400 years the whole route between Europe and the far east passed across these mountains, and only ceased on the discovery by the Portuguese of the route round the Cape. Three roads, leaving the Red Sea at Berenice, Kosseir, and Myos Hormos, converged upon Koptos on the Nile, and were used according to circumstances. The crowning interest of these mountains lies in the ancient quarries scattered among their lofty peaks and winding valleys, and which were worked perhaps five or six thousand years ago. But for many years a sleep has fallen over these mountains; the ring of hammers was no longer heard, and the wells along the desert roads had become choked with sand. But a period of awakening has begun. Twenty years ago the Marquis of Bassano, with his thousand workmen, began digging in the Gimsa Well for sulphur; last year a colony of bearded miners set up their derricks and boring engines on Jebel Zeit, the oil mountain; and last the fine porphyry, which can be matched nowhere in the world, is once more being quarried, and Mr. Brindley, of London, is actually the direct successor of Epaphroditos, the imperial freedman of Vigirium, whom the Greek inscriptions show to have been the last lessee in the year 147 A.D.—more than seventeen hundred years ago.

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6. *Trade Prospects with the Sudan.*[2] *By* Major Watson, *R.E., C.M.G.*

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7. *Account of a recent Visit to the ancient Porphyry Quarries of Egypt.* *By* W. Brindley, *F.R.M.S.*

Egyptian porphyry has been sought after from the earliest times, as one of the most precious building stones. Ancient writers differed as to the whereabouts of the quarries from which that stone was obtained, and in modern times they were literally rediscovered by Burton and Wilkinson in 1823, and subsequently visited by Lepsius in 1845. The information published by these visitors proving of no immediate practical value, the author determined to follow in the footsteps of Wilkinson, and, accompanied by his wife, he came to Cairo in February last.

[1] Published in the *Proceedings of the Royal Geographical Society*.

[2] This paper will be published in the *Journal of the Manchester Geographical Society*.

Having examined the ancient granite quarries at the first cataract, which supplied deep red, rose, and dark grey stone, which was quarried by metal wedges, and not wood (as is generally supposed), the author started from Keneh with a small caravan and supplies calculated to last three weeks. Passing the remains of several Roman stations, the author, on the fifth day, reached an excellent well in the charming Wadi Kitar, hemmed in on three sides by precipitous mountains. Soon after leaving this valley he crossed the watershed (2,400 feet above the Nile), and then travelled along the flank of the immense porphyry mountain of Gebel Dukhan as far as an old Roman station with an old fort. The morning after his arrival the author ascended to the top of a pass (3,100 feet), without having found even a fragment of porphyry; but espying, by the aid of a good field-glass, porphyry colouring on the opposite mountain he resolved to go there, and his delight knew no bounds when he found the ground there strewn with pieces of the most sumptuous porphyry, and discovered a pitched way or slide, 16 feet wide, down which the blocks were lowered. Further examination led him to the locality where the Romans had extracted their grandest masses, and he found that these quarries had yielded not only the usual spotted variety but also the brecciated sorts and green-greys. The great quarry was at an altitude of 3,650 feet above the sea, and a road led down to it to an ancient town with workshops. A path led hence to the old town in the valley, further up which are the ruins of a Roman temple. The blocks were formerly carried to the Nile, a distance of 96 miles, but they will in future be conveyed by a gentle incline to the Red Sea, which is about 25 miles distant. On his return to Cairo the author secured a concession to rework the quarries, the terms of which have since been ratified.

8. *On the Red Sea Trade.*[1] *By* A. B. Wylde.

9. *Matabeleland and the Country between the Zambezi and the Limpopo.* *By* Captain C. E. Haynes, *R.E.*

This region has been famous from a very early age for its productive gold mines. They were being worked when the Portuguese first arrived in the country, and some of the mines still exist, but the slave trade and the inroad of the Matabele power have reduced all native industries to a very indeterminate quantity.

The Matabele are the near kinsmen of the Zulu, and have nearly identical customs. Both wear that unique head-dress, the gum-ring, their badge of manhood. The Matabele were driven out of Zululand about the beginning of the century, and under their chief Umselikazi they became a terror to all the Bechuana tribes living north of the Vaal river. Attacked by the Voortrek Boers, and by the Zulus under Panda, they were forced to retire north of the Limpopo, and finally settled down in the midst of the Makalaka and Mashona tribes. About the same period the Gaza kingdom was established by Manikuza, one of Chaka's generals, to the east of the Sabi river. This tribe, under the government of Umzila, proved itself a fast ally of the Matabele.

The invasion of the Matabele has caused the annihilation or disruption of the tribes with whom they came into conflict. There are only fragments of the aboriginal people now, who still carry on in a furtive manner some of their old industries, such as gold digging, iron working, and weaving.

The climate of Matabeleland resembles that of the Transvaal, and the high veldt which ranges from the Nata river to the vicinity of the Zambezi near Tete, is well fitted for European settlers, and promises to become a prosperous agricultural region, with numerous local markets at hand in the mining districts. Care should be taken to protect the forests there. Their wholesale destruction has already begun. The Gaza country and the low veldt is not so salubrious, and, generally speaking, the Zambezi valley is malarious.

[1] This paper will be published in the *Journal of the Manchester Geographical Society*.

Agriculture at present is in a depressed state. There is plenty of arable land on the high veldt and excellent wheat, as all English vegetables alongside the banana and orange can be grown. The high and middle veldts are more suitable for stockfarming. Facilities for irrigation abound. The tsetse does not exist on the high veldt. The mineral wealth of the country still awaits development. The Tati gold-field is now being worked by an English company, but a nod from the Matabele king may at any time put an end to this. It is a pity that this infant colony should not have been made the basis from which British interests in Matabeleland might be protected. The extension of the railway from Kimberley to the Tati mines would have a most beneficial effect in attracting settlers. Complaints have lately been made that northern Bechuanaland is gradually drying up, and it is not difficult to prove that at one time Lake Ngami was drained through the Botletle, Lake Makarikari, and the Shashi into the Limpopo.

10. *A Note on Houghton, the African Traveller.*[1]
By Major Sir HERBERT PERROT.

1_. *Western Australia.*[1] *By* JOHN FORREST, *C.M.G.*

12. *Second Report of the Committee appointed for the purpose of reporting upon the Depth of Permanently Frozen Soil in the Polar Regions.*—See Reports, p. 152.

SATURDAY, SEPTEMBER 3.

The Section did not meet.

MONDAY, SEPTEMBER 5.

The following Papers and Report were read:—

1. *The Beginning of the Geography of Great Britain.*[1]
By Professor W. BOYD DAWKINS, *F.R.S.*

2. *Report of the Committee for co-operating with the Royal Geographical Society in endeavouring to bring before the authorities of the Universities of Oxford and Cambridge the advisability of promoting the study of Geography by establishing special Chairs for the purpose.*—See Reports, p. 158.

3. *Geography at the Universities.*[1] *By* H. J. MACKINDER, *M.A.*

4. *The Ruby Mines of Burma.*[1] *By* J. SKELTON STREETER.

[1] Published in the *Proceedings of the Royal Geographical Society.*

5. *Siam.* *By* J. McCarthy.

6. *The Valley of the Rio Dôce (Brazil).* *By* William John Steains.

The author in 1881 left England for Brazil, in the employ of Messrs. Hugh Wilson & Son, contractors for the construction of a railway in the flourishing little province of Alagaõs. On the completion of this railway the author, at his own expense, undertook an exploration of the Rio Dôce and of its northern tributaries, which, notwithstanding his narrow means, and in the face of considerable physical obstacles, he carried to a successful conclusion. His expedition left Rio de Janeiro on June 7, 1885, and for eight weary months it had to battle against hardships and privations, such as want of provisions, inhospitable natives, fevers, and ague.

The valley of the Rio Dôce is one of the most fertile regions of the empire. Virgin forests cover nearly the whole of it. Gold is found in Cuithé, a district of Minas Geraes, close to the right bank of the Dôce, as also on the headwaters of the Rio Tambaquary, a tributary of the Sussuhy Grande. Most of the basin of the Rio Dôce is inhabited by wild Botocudo Indians, who possess an inborn hatred of the white man, who, on his side, looks upon these 'Bugres' with feelings of intense horror and dread. Until these wild Indians shall at least have been partially civilised, the valley of the Rio Dôce must necessarily remain a sealed Paradise. The few attempts made hitherto in this direction have hopelessly failed, perhaps because of the gross mismanagement on the part of those to whom the task was entrusted.

The author's arduous explorations have resulted in a carefully plotted map of the Rio Dôce and of its tributaries, based upon over 4,000 magnetic bearings and careful dead reckonings.

7. *On South-Eastern Alaska.* *By* Professor Libbey.

TUESDAY, SEPTEMBER 6.

The following Reports and Papers were read.—

1. *Final Report of the Committee on the production of a Bathy-hypsographical Map of the British Islands.*—See Reports, p. 160.

2. *On some Defects of the Ordnance Survey.* *By* S. H. Wilkinson, *M.A.*

The Ordnance Survey does not give us detailed maps of Great Britain on scales reduced from 1 : 63000, which are much wanted.

The representation of the ground in both the 1-inch and the 6-inch maps is inadequate.

3. *On the Utilisation of the Ordnance Survey.* *By* Colonel Sir Charles Wilson, *K.C.B., F.R.S.*

4. *On the United States Geographical and Geological Survey.* *By* Josiah Pierce, jun.

5. *On a Bathy-orographical Map of Scotland.*[1] *By* H. R. Mill, *D.Sc.*

[1] To be published in the *Scottish Geographical Magazine.*

6. *A Plea for the Metre.* *By* E. G. Ravenstein, *F.R.G.S.*

The author pointed out the great advantages of the metre as a universal international standard of length. There were at present in use three international measures of length, viz., the English foot, in countries covering 18,188,112 square miles, with 471 millions of inhabitants, the metre (12,671,200 square miles, 347,091,000 inhabitants), and the Castilian foot (752,901 square miles, 5,905,000 inhabitants). The English foot, at present in use throughout the British and Russian empires, in the United States, and in some other countries, appeared to gain no new adherents, whilst the metre was still engaged upon a career of conquest. Denmark and Russia were the only countries in Europe which had not as yet adopted it. The metrical system appeared to him to present great advantages to business men, and in 1885 nearly one-half the commercial transactions of the country were carried on with countries using the metre. The time at present expended in our schools upon acquiring a knowledge of an absurdly complicated system of weights and measures might be devoted to more useful objects. To geographers and statisticians the universal acceptance of the metre would prove an immense boon. Scientific men in other departments had freely adopted the metre, and geographers should follow this laudable example. Owing, however, to the intimate connexion of geography with the common affairs of life he despaired of the general acceptance of the metre until it should have become the legal standard of length.

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7. *Second Report of the Committee for drawing attention to the desirability of further Research in the Antarctic Regions.*

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8. *Formosa.* *By* A. R. Colquhoun.

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9. *On the Study of the Natural Divisions of the Earth, rather than the National ones, as the Scientific Basis of Commercial Geography.* *By* John Yeats, *LL.D.*

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10. *On a Natural Method of Teaching Geography.* *By* John J. Cardwell.

The author proposes to approach his subject from the traveller's standpoint, both as to the order of development, external survey, exploration of the interior, deductions and inferences, and the threefold method of treatment—exploring, mapping out, and describing—as also by giving no information which the pupils may possibly be able to deduce from the map themselves.

The author thus deals successively with (1) the bearings of the country to be explored, relatively to surrounding centres, and absolutely as regards its position on the globe; (2) the external survey of the country, such as coast-line and land frontiers, which he effects in a sail along the coast and in a balloon voyage; (3) the exploration of the interior in a series of excursions up the rivers and the mountains; (4) productions of agriculture, manufacture, and mining, as also means of communication. The information thus imparted is to be appropriated by the pupils (1) by learning off by heart the short notes taken down in class; (2) by writing out, without notes, descriptions of the scenery, &c., of the different parts of the country explored; (3) by learning to draw from memory a map of the country.

The author fully explained his method with the aid of diagrams and on the blackboard.

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11. *The Teaching of Geography in the Elementary Schools of England.* *By* A. Park.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION—ROBERT GIFFEN, LL.D., V.P.S.S.

THURSDAY, SEPTEMBER 1.

The PRESIDENT delivered the following Address:—

The Recent Rate of Material Progress in England.

IN coming before you on this occasion it has occurred to me that a suitable topic in the commercial capital of England, and at a time when there are many reasons for looking around us and taking stock of what is going on in the industrial world, will be whether there has been in recent years a change in the rate of material progress in the country as compared with the period just before. Some such question is constantly being put by individuals with regard to their own business. It is often put in political discussions as regards the country generally, with some vague idea among politicians that prosperity and adversity, good harvests and bad, in the most general sense, depend on politics. And it must always be of perennial interest. Of late years it has become specially interesting, and it still is so, because many contend that not only are we not progressing, but that we are absolutely going back in the world, while there are evident signs that it is not so easy to read in the usual statistics the evidence of undoubted growth as it was just before 1870–73. The general idea, in my mind, I have to add, is not quite new. I gave a hint of it in Staffordshire last winter, and privately I have done something to propagate it so as to lead people to think on what is really a most important subject. What I propose now to do is to discuss the topic formally and fully, and claim the widest attention for it that I possibly can.

There is much *primâ facie* evidence, then, to begin with, that the rate of the accumulation of wealth and the rate of increase of material prosperity may not have been so great of late years, say during the last ten years, as in the twenty or thirty years just before that. Our fair-trade friends have all along made a tactical mistake in their arguments. What they have attempted to prove is that England lately has not been prosperous at all, that we have been going backwards instead of advancing, and so on; statements which the simplest appeal to statistics was sufficient to disprove. But if they had been more moderate in their contentions, and limited themselves to showing that the rate of advance, though there was still advance, was different from and less than what it was, I for one should have been prepared to admit that there was a good deal of statistical evidence which seemed to point to that conclusion, as soon as a sufficient interval had elapsed to show that the statistics themselves could not be misinterpreted. There has now been ample time to allow for minor variations and fluctuations, and the statistics can be fairly construed.

I have to begin by introducing a short table dealing with some of the principal statistical facts which are usually appealed to as signs of general progress and the reverse, and I propose to go over briefly the items in that table and to discuss along with them a few broad and notorious facts which cannot conveniently be put in the same form.

Statement as to production or consumption of staple articles in the United Kingdom in the undermentioned years, with the rate of increase in different periods compared.

	1855	1865	1875	1885	Ratio of increase %		
					1855-65	1865-75	1875-85
Income Tax assessments, mlln. £	308	396	571	631	28	44	10
Production of coal, million tons	64	98	132	159	53	35	20
" pig iron "	3·2	4·8	6·4	7·4	50	33	16
Receipts from railway goods traffic per head of population	—	11*s.*[1]	18*s.*[1]	21*s.* 2*d.*[1]	—	63	18
Clearances of shipping in foreign trade, million tons	10	15	24	32	50	60	33
Consumption of tea per head, lbs.	2·3	3·3	4·4	5·0	43	33	13½
" sugar " "	30·6	39·8	62·7	74·3	30	58	19

The first figures are those of the income tax assessments. What we find is that if we go back thirty years and compare the amount of income tax assessments in the United Kingdom at ten years' intervals, there appears to be an immense progress from 1855 to 1875, the first twenty years, and since 1875 a much less progress. The total amount of the assessments themselves, stated in millions, was as follows:—

	Millions		Millions
1855 . . .	£308	1875 . . .	£571
1865 . . .	396	1885 . . .	631

And the rate of growth in the ten yearly periods which these figures show is—between 1855 and 1865, 28 per cent.; between 1865 and 1875, 44 per cent.; and between 1875 and 1885, 10 per cent. only.

Making all allowance for changes in the mode of assessment by which the lower limit of the tax has been raised, for the apparent increase before 1875 which may have been due to a gradual increase of the severity of the collection, and for the like disturbing influences, I believe there is no doubt that these income tax assessments correspond fairly well to the change in the money value of income and property in the interval. How great the change in the rate of increase is, is shown by the simple consideration that if the rate of increase in the last ten years, instead of being 10 per cent. only, had been 44 per cent., as in the ten years just before, the total of the income tax assessments in 1885, which is actually 631 millions, would have been 882 millions! Something then has clearly happened in the interval to change the rate of increase.

These figures being those of money values, an obvious explanation is suggested which would account in great part for the phenomenon of a diminished rate of increase in such values without supposing a reduction of the rate of increase of real wealth, of the things represented by the money values, to correspond. This is the fall of prices of which we have heard so much of late years, and about which in some form or another we shall no doubt hear something at our present meeting. It is quite clear that if prices fall then income tax assessments must also be affected. The produce of a given area of land, for instance, sells for less than it would otherwise sell; there is less gross produce, and in proportion there is even less net produce, that is, less rent; consequently the net income appearing in the Income Tax Schedules is either less than it was or does not increase as it did before. The same with mines, with railways, and with all sorts of business under Schedule D. The things themselves may increase as they did before, but as the money values do not increase but diminish, the income tax assessments cannot swell at the former rate. It is the same with salaries and other incomes not dependent so directly in appearance on the fall in prices. Salaries and incomes are of course related to a given range of prices of

[1] These figures are for 1860–64, 1870–74, and 1880–84.

commodities, and a fall in the prices of commodities implies that the range of salaries and incomes is itself lower than it would otherwise be, assuming the real relation between the commodities and incomes to be the same after the fall in prices as it would have been if there had been no fall in prices. Hence the income tax assessments by themselves are not a perfectly good test in a question like the present. The change implied may be nominal only, so far as the aggregate wealth and prosperity of the community are concerned, though of course there can be no great and general fall of prices without a considerable redistribution of wealth, which must have many important consequences.

This criticism, however, does not apply to the remaining figures in the short table submitted, and to various other well-known facts, which we shall now proceed to discuss.

The production of coal, then, is found to have progressed in the last thirty years as the income tax assessments have done. The figures in millions of tons at ten years' intervals are as follows:—

	Million Tons		Million Tons
1855	64	1875	132
1865	98	1885	159

And the rate of growth in the ten yearly periods which these figures show is between 1855 and 1865, 53 per cent.; between 1865 and 1875, 35 per cent.; and between 1875 and 1885, 20 per cent. only. The rate of growth in the last ten years is much less than in the twenty years just before. The percentages here, it will be observed, are higher than in the case of the income tax assessments. The increase in the last ten years in particular is 20 per cent. as compared with an increase of 10 per cent. only in the income tax assessments. But the direction of the movement is in both cases the same.

I need hardly say, moreover, that coal production has usually been considered a good test of general prosperity. Coal is specially an instrumental article, the fuel of the machines by which our production is carried on. Whatever the explanation may be, we have now, therefore, to take account of the fact that the rate of increase of the production of coal has been less in the last ten years than in the twenty years just before.

Then with regard to pig-iron, which is also an instrumental article, the raw material of that iron which goes to the making of the machines of industry, the table shows the following particulars of production:—

	Million Tons		Million Tons
1855	3·2	1875	6·4
1865	4·8	1885	7·4

And the rate of growth which these figures show is between 1855 and 1865, 50 per cent.; between 1865 and 1875, 33 per cent.; and between 1875 and 1885, 16 per cent. only. Whatever the explanation may be, we have thus to take account of a diminution of the rate of increase in the production of pig-iron, much resembling the diminution in the rate of increase of the production of coal.

At the same time the miscellaneous mineral production of the United Kingdom has mostly diminished absolutely. On this head, not to weary you with figures, I have not thought it necessary to insert anything in the above short table; but I may refer you to the tables put in by the Board of Trade before the Royal Commission on Trade Depression. Let me only state very briefly that while the average annual amount of copper produced from British ores amounted in 1855 to over 20,000 tons, in 1865 the amount was about 12,000 tons only, in 1875 under 5,000 tons, and in 1885 under 3,000 tons. As regards lead, again, while the production about 1855 was 65,000 tons, and in 1865 about 67,000 tons, the amount in 1875 had been reduced to 58,000 tons, and in 1885 to less than 40,000 tons. In white tin there is an improvement up to 1865, but no improvement since, and the only set-off, a very partial one, is in zinc, which rises steadily from about 3,500 tons in 1858, the earliest date for which particulars are given, to about 10,000 tons in 1885, considerably higher figures having been touched in 1881–83

There is nothing, then, in these figures as to miscellaneous mineral production to mitigate the impression of the diminution in the rate of increase in the great staples, iron and coal, in recent years.

Agricultural production, it is also notorious, has been at any rate no better, or not much better, than stationary for some years past, although down to a comparatively recent period a steady improvement seemed to be going on. Making all allowance for the change in the character of the cultivation, by which the gross produce is diminished, although the net profit is not affected to the same extent, and which might be held to argue no real decline in the rate of general growth if the population, diverted from agriculture, were more profitably employed, yet the facts, broadly looked at, taken in connection with the other facts stated as to diminished rate of increase in other leading industries, seem to confirm the supposition that there may have been some diminution in the rate of increase generally.

It is, unfortunately, impossible to state in a simple manner the progress at different dates in the great textile industries of the country. Everything as regards these industries is thrown out by the disturbance consequent on the American War. It does not appear, however, that what has happened as regards the main textile industries, cotton and wool, would alter sensibly the conclusions above stated, drawn from the facts as to other main industries of the country. If we take the consumption of raw materials as the test, it would appear that the growth in the cotton manufacture is from a consumption of 28 lbs. per head in 1855 to about 38 lbs. per head in 1875, while in 1885 the consumption is nearly 42 lbs. per head, an increase of 4 lbs. per head in the last ten years, against 10 lbs. per head in the previous twenty. The percentage of increase in the last twenty years must therefore, on the whole, have been less than in the previous twenty, although in these twenty years the great interruption due to the American Civil War occurred. Of course the amount of raw material consumed is not here an absolute test. There may be more spinning and weaving now in proportion to the same quantity of raw material than was formerly the case. But the indications are at least not so certain and direct as when the consumption of raw material could be confidently appealed to. As regards wool the comparison is unfortunately very incomplete owing to the defect of data for the earlier years; but what we find is that the amount of wool consumed per head of the population of the United Kingdom has in the last ten years rather declined than otherwise from nearly 11 lbs. per head in the five years 1870–74 to 10 lbs. per head only in the five years 1880–84. Here, again, the explanation suggested as to cotton—viz., that there may be more spinning and weaving now in proportion to the same quantity of raw material than was formerly the case—applies. But the answer is also the same, that at any rate the indications of progress are no longer as simple as they were. The reality of the former rate of advance is not so clearly manifest.

Of course I need hardly add that in the case of another great textile, silk, there has been no progress, but the reverse, for some years; that this is also true of linen; and that the increase in the allied manufacture, jute, can only be a partial set-off.

In the textiles, then, as in other staple industries of the country, the rate of advance in the last ten years, measuring by things, and not merely by values, has been less than in the twenty years immediately before.

We pass on, then, to another set of figures included in the short table above submitted. We may look not only at leading industries of production directly, but at the broad figures of certain industries which are usually held to reflect, as in a mirror, the progress of the country generally. I refer to the railway traffics as regards the home industries of the country, and the entries and clearances of shipping in the foreign trade as regards our foreign business.

As regards railways what we find is, if we take the receipts from the goods traffic in the form in which they were summarised for the Royal Commission on Trade Depression, viz., reduced to so much per head of the population on the average of quinquennial periods, that in the five years 1860–64, which is as far back as the figures can be carried, the receipts per head were 11*s.*; ten years later, viz., in 1870–74, the receipts per head were 18*s.*; and ten years later, viz.,

1880–84, the receipts per head were 21*s.* 2*d.* The rate of growth shown in the first ten years' interval is 63 per cent.; in the second ten years' interval it is only 18 per cent.; and in the last year or two, I may add, there has been no further improvement. Here the question of the value of money comes in again, but this would only partially modify the apparent change. There is also a question as to railway extension having been greater in the earlier than in the later period, so that growth took place in the earlier period because there were railways in many districts where they had not been before, and there was no room for a similar expansion in the later period. But the difference in the rate of growth it will be observed is very great indeed, and this explanation seems hardly adequate to account for all the difference. At any rate, to repeat a remark already made, the indications are no longer so simple as they were. There is something to be explained.

The figures as to the number of tons of goods carried are not in the above table; nor are such figures very good, so long as they are not reduced to show the number of tons conveyed one mile. But, *quantum valeant*, they may be quoted from the Board of Trade tables already referred to. The increase, then, in minerals conveyed between 1855 and 1865 is from about 40 million to nearly 80 million tons, or 100 per cent.; between 1865 and 1875 it is from 80 to about 140 million tons, or 75 per cent.; and in the last ten years it is from 140 to 190 million tons only, if quite so much, or about 36 per cent. only. As regards general merchandise, again, the progression in the three ten-yearly periods is in the first from about 24 to 37 million tons, or rather more than 50 per cent.; in the second from 37 to 63 million tons, or 70 per cent.; and in the third from 63 to 73 million tons, or 16 per cent. only. As far as they go there is certainly nothing in these figures to oppose the indications of a falling-off in the rate of increase of general business already cited.

Coming to the movement of shipping in the foreign trade the series of figures we obtain are the following, which relate to clearances only, those relating to entries being of course little more than duplicate, so that they need not be repeated: 1855, 10 million tons; 1865, 15 million tons; 1875, 24 million tons; 1885, 32 million tons. And the rate of growth thus shown is between 1855 and 1865 no less than 50 per cent.; between 1865 and 1875 no less than 60 per cent.; and between 1875 and 1885 about 33 per cent. only—again a less rate of increase in the last ten years than in the period just before. Here, too, it is to be noticed, what is unusual in shipping industry, that in the last few years the entries and clearances in the foreign trade have been practically stationary. The explanation no doubt is in part the great multiplication of lines of steamers up to a comparatively recent period, causing a remarkable growth of the movement while the multiplication of lines was itself in progress, and leaving room for less growth afterwards because a new framework had been provided within which traffic could grow. But here again it is to be remarked that the whole change can hardly, perhaps, be explained in this manner, while the remark already made again applies, that the fact of explanation being required is itself significant.

The figures of imports and exports might be treated in a similar manner, as they necessarily follow the course of the leading articles of production and the movements of shipping. But we should only by so doing get the figures we have been dealing with in another form, and repetition is of course to be avoided.

The short table contains only another set of figures, viz. those of the consumption of tea and sugar, which are again commonly appealed to as significant of general material progress. What we find as regards tea is that the consumption per head rises between 1855 and 1865 from 2·3 to 3·3 lbs., or 43 per cent.; between 1865 and 1875 from 3·3 to 4·4 lbs., or 33 per cent.; and between 1875 and 1885 from 4·4 to 5 lbs., or 13½ per cent. In sugar the progression is in the first period from 30·6 to 39·8 lbs. per head, or 30 per cent.; in the second period from 39·8 to 62·7 lbs., or 58 per cent.; and in the third period from 62·7 to 74·3 lbs., or 19 per cent. only. In the last ten years in both cases the rate of increase is less than in the twenty years before.

These facts, I need hardly say, would be strengthened by a reference to the consumption of spirits and beer, the decline in the former being especially notorious.

In tobacco again in the last ten years there has been no increase of the consumption per head; which contrasts with a rapid increase in the period just before—viz., from about 1·31 lb. per head in 1865 to 1·46 lb. per head in 1875.

No doubt the observation here applies that the utmost prosperity would obviously be consistent with a slower rate of increase per head from period to period in the consumption of these articles, and with, in the end, a cessation of the rate of increase altogether. The consumption of some articles may attain a comparatively stationary state, the increased resources of the community being devoted to new articles. But here, again, we have to observe the necessity for explanation. The indications are no longer so sure and obvious in all directions as they were.

It is difficult, indeed, to resist the impression made when we put all the facts together, leaving out of sight for a moment those of values only. We are able to affirm positively—(*a*) That the production of coal, iron, and other staple articles has been at a less rate in the last ten years than formerly; (*b*) that this has taken place when agricultural production has been notoriously stationary, and when the production of other articles such as copper, lead, &c., has positively diminished; (*c*) that there has been a similar falling-off in the rate of advance in the great textile industries; (*d*) that the receipts from railway traffic and the figures of shipping in the foreign trade show a corresponding slackening in the rate of increase in the business movement; and (*e*) that the figures as to consumption of leading articles, such as tea, sugar, spirits, and tobacco, in showing a similar decline in the rate of increase, and, in some cases, a diminution, are at least not in contradiction with the other facts stated, although it may be allowed that there was no antecedent reason to expect an indefinite continuance of a former rate of increase.

From these facts, however, we may qualify them: and many qualifications have already been suggested while others could be added: it seems tolerably safe to draw the conclusion that there has probably been a falling-off in the rate of material increase generally. The income tax assessment figures, though they could not be taken by themselves in such a question, are, at least, not in contradiction, and there is nothing the other way when we deal with these main figures only. I should not put the conclusion, however, as more than highly probable. Some general explanation of the facts may be possible on the hypothesis that there is no real decline in the rate of growth generally at all; that the usual signs for various reasons have become more difficult to read; that owing to the advance already made the real growth of the country and, to some extent, of other countries, has taken a new direction; and that the utmost caution must be used in forming final conclusions on the subject. But the conclusion of a check having occurred to the former rate of growth may be assumed meanwhile for the purposes of discussion. The attempted explanation of the causes of change, on the hypothesis that there is a real change, may help to throw light on the question of the reality of the change itself.

Various explanations are suggested, then, not only for a decline in the rate of our progress, but for actual retrogression. Let us look at the principal of these explanations in their order and see whether they can account for the facts: either for actual retrogression, or for a decline in the general rate of material growth equal to what some of the particular facts above cited, if they were significant of a general change in the rate of growth, imply—a decline, say, from a rate of growth amounting to 40 per cent. in ten years to one of 20 per cent. only in the same period.

One of the most common explanations, then, as we all know, is foreign competition. The explanation has been discredited because of the exaggeration of the alleged evil to be explained; but it may possibly be a good enough explanation of the actual facts when they are looked at in a proper way. In this light, then, the assertion as to foreign competition would be found to mean that foreigners are taking away from us some business we should otherwise have had, and that, consequently, although our business on the whole increases from year to year, it does not increase so fast as when foreign competition was less. Those who talk most about foreign competition have actually in their mind the unfair element in that

competition, the stimulus which the Governments of some foreign countries give or attempt to give to particular industries by means on the one hand of high tariffs keeping out the goods we should otherwise send to such countries, and giving their home industry of the same kind a monopoly which sometimes enables them to produce a surplus they can sell ruinously cheap abroad, and, by means on the other hand of direct bounties which enable certain industries to compete in the home market of the United Kingdom itself as well as in foreign markets. But there is a natural foreign competition as well as a stimulated foreign competition to be considered, and it may be the more formidable of the two.

Dealing first with the stimulated competition, the most obvious criticism on this alleged explanation of the recent decline in the rate of increase of our material progress is that the stimulus given by foreign Governments in recent years has not been increasing, or, at any rate, not materially increasing, so as to account for the change in question. People forget very quickly; otherwise it would not be lost sight of that after 1860, as far as European nations are concerned, there was a great reduction of tariff duties—a change, therefore, in the contrary direction to that stimulus which is alleged to have lately caused a change in the rate of our own development. Since about five or six years ago the movement on the Continent seems again to have been in the direction of higher tariffs. France, Italy, Austria, Germany, and Russia have all shown protectionist leanings of a more or less pronounced kind. Some of our colonies, especially Canada, have moved in the same direction. But, on the whole, these causes as yet have been too newly in operation to affect our industry on a large scale. As a matter of fact, with one exception to be presently noticed, the period from 1860 to 1880 was one in which the effect of the operation of foreign Governments in regard to their tariffs could not be to stimulate additional competition of an injurious kind with us in the way above described, but to take away, if anything, from the stimulus previously given. The changes quite lately brought into operation, if big enough, and if really having the effects supposed, might stimulate foreign competition in the way described in the period now commencing; but, as an explanation of the past facts, it is impossible to urge that foreign competition had recently been more stimulated by additions to tariffs than before, and that in consequence of this stimulus our own rate of advance had been checked.

The one exception to notice is the United States. Immediately after 1860 the civil war in that country broke out, and that war brought with it the adoption of a very high tariff. Curiously enough, however, that tariff operated most against us in the very years—that is, the years before 1875—in which our rate of advance was greater to all appearance than it has lately been. In 1883 there was a great revision of the tariff, having for its general result a slight lowering and not an enhancement of the tariff, and it is with this reduction—that is, with a diminution of the alleged adverse stimulus—that the diminution in our own rate of advance has occurred.

Of course the explanation may be that, although Governments have not themselves been active till quite lately in adding to their tariffs, yet circumstances have occurred to make the former tariffs more injurious in recent years than they were down to 1875. For instance, it may be said that owing to the fall of prices in recent years the burden of specific duties has become higher than it was. The duty is nominally unchanged, but by the fall of prices its proportion to the value of the article has become higher. This is no doubt the case to a large extent. On the other hand *ad valorem* duties have been lowered in precisely the same way. The fall of prices has brought with it a reduction of duty, and especially on articles of English manufacture, where the raw material is obtained from abroad, the reduction of duty, being applicable to the whole price, must certainly have had for effect to render more effective than before the competition of the English manufacturer. Whether on the whole the reduction of *ad valorem* duties consequent on the fall of prices has been sufficient throughout the range of our foreign trade to compensate the virtual increase of the weight of specific duties from the same cause seems to be a nice question. This being the case, it must be very difficult indeed to show that, on the whole, the weight of foreign tariffs, apart from the action of foreign

Governments, has been increased in recent years so as to affect our own growth injuriously.

Foreign tariffs, it may be said, have become more effective for another reason. Manufacturing industry having itself developed abroad, the same amount of protection given to the foreign industry becomes more efficient than it was. But this, of course, raises the question of the effect of natural foreign competition, which will presently be discussed.

So much for the stimulus to foreign competition due to high tariffs. With regard to bounties very little need be said. They have been the subject of much discussion and agitation for various reasons, and in what I have to say I propose not to touch on the practical question whether these bounties are injurious, and the nature of the political remedies that may or may not be possible. I limit myself strictly to the point, how far any effect which such bounties can have had would account for a diminution in the rate of material growth of the country generally in the last ten years as compared with the ten years just before. Dealing with the question in this strictly limited fashion, what I have to observe first is that hitherto very few bounties have been complained of, except those on sugar production and refining; and next that the whole industries of sugar production and refining, important as they are in themselves, hardly count in a question of the general industry of the United Kingdom. Even if we refined all the sugar consumed in the United Kingdom and the maximum amount we have ever exported, the whole income from this source, the whole margin, would not exceed about 2,000,000*l*. annually, not one-six-hundredth part of the income of the people of the United Kingdom; and of this 2,000,000*l*. at the worst we only lose a portion by foreign competition, while all that is really lost, it must be remembered, is not the whole income which would have been gained if a certain portion of our labour and capital had been employed in sugar refining, but only the difference between that income and the income obtained by the employment of the same labour and capital in other directions. The loss to the empire may be greater because our colonies are concerned in sugar production to the extent at present prices of 5,000,000*l*. to 6,000,000*l*. annually, which would probably be somewhat larger but for foreign competition. But it does not seem at all certain that this figure would be increased if foreign bounties were taken away, while in any case the amounts involved are too small to raise any question of foreign bounties having checked the rate of growth of the general industry of the country.

Per contra, of course, the extra cheapness of sugar, alleged to be due to the bounties, must have been so great an advantage to the people of the United Kingdom, saving them perhaps 2,000,000*l*. to 3,000,000*l*. per annum, that the stimulus thereby given to other industries must apparently have far more than compensated any loss caused by the stimulus of foreign bounties to sugar production and refining abroad. But to enlarge on this point would involve the introduction of controversial matter, which I am anxious to avoid. I am content to show that nothing that can have resulted from sugar bounties could have affected seriously the general rate of material growth in the country.

Mutatis mutandis, the same remarks apply to other foreign bounties, of which indeed the only ones that have been at all heard of are those on shipping. But as yet, at least, the increase of foreign shipping has not been such as to come into comparison with our own increase, while the portion of the increase that can be connected with the operation of bounties is very small. It would be useless to enter into figures on so small a point; but few figures are so well known or accessible as those relating to shipping.

In neither way, then, does there appear to be anything in the assertion that the protectionist action of foreign Governments in recent years can have caused the check alleged to the rate of growth in our industry generally, assuming such a check to have occurred. I may be dispensed, therefore, from entering on the theoretical argument, which I only notice *pour mémoire,* that in the nature of things no enhancement of foreign tariffs and no grants of foreign bounties could really check

See Appendix to *First Report of Royal Commission on Trade Depression,* p. 130.

our own rate of growth, except by checking foreign growth still more, which is not the case we are considering, because the allegation is that foreign competition is increasing at our expense. That I do not insist on this argument is not to be considered as a sign that it is dropped or that I am not fully sensible of its logical completeness. It seems enough, at present, to fortify it by considerations from actual practical facts which no one can dispute.

The question of an increase of foreign competition from natural causes is more difficult. It is beyond all question, as I have pointed out elsewhere, that foreign competition in every direction from natural causes must continue to increase, and that it has increased greatly in recent years. But when the facts are examined, it does not appear that this competition has been the cause of a check to our own rate of growth. One of the facts most commonly dwelt upon in this connection is the great increase of the imports of foreign manufactured articles into the United Kingdom. But the increase in the last ten years is not more than about 18,000,000*l.*, taking the facts as recorded in what is known as Mr. Ritchie's return, viz., from about 37,000,000*l.* in the quinquennial period 1870–74 to 55,000,000*l.* in the quinquennial period 1880–84, or about 50 per cent. Out of 18,000,000*l.* increased imports of such articles it is fair to allow that at least one-half, if not more, is the value of raw material which we should have had to import in any case; so that only 9,000,000*l.* represents the value of English labour displaced by these increased imports. Even the whole of this 9,000,000*l.* of course is not lost, only the difference between it and the sum which the capital and labour 'displaced' earns in some other employment, which may possibly even be a *plus* and not a *minus* difference. If we add articles 'partly manufactured' no difference would be made, for the increase here is only from 26,000,000*l.* to 28,000,000*l.* in the ten years. Such differences, it need not be said, hardly count in the general total of the industry of the country. Further, the rate of increase of these imports was just as great in the period when our own rate of growth was greater as in the last ten years, the increase in manufactured articles between 1860–64 and 1870–74 being 19,000,000*l.*, viz., from 18,000,000*l.* to 37,000,000*l.*, or over 100 per cent. as compared with 50 per cent. only in the last ten years, and in articles partly manufactured from 17,000,000*l.* to 26,000,000*l.*, an increase of 9,000,000*l.* as compared with an increase of 2,000,000*l.* only in the last ten years. Making all allowance for the fall in prices in recent years, these figures still show a greater relative increase of imports of manufactured articles before 1875 than afterwards. It cannot, therefore, be the increased import of foreign manufactures which has caused the check to our own growth in the last ten years.

But foreigners, it is said, exclude us from their own markets and compete with us in foreign markets. Here again, however, we find that any check which may have occurred to our foreign export trade is itself so small that its effect on the general growth of the country would be almost *nil.* Take it that the check is as great as the diminution in the rate of increase in the movements of shipping, viz., from an increase of about 55 per cent. to one of 33 per cent. only, that is, broadly speaking, a diminution of one-third in the rate of increase of our foreign trade, whatever that rate may have been. Assuming that rate to have been the same as the rate of increase in the movements of shipping itself, the change would be from a rate of increase equal to one-half in ten years to a rate of increase equal to about one-third only. Applying these proportions to the exports of British and Irish produce and manufactures, which represent the productive energy of the country devoted to working for foreign exchange, and assuming that ten years ago the value of British labour and industry in the produce and manufactures we exported, due deduction being made for the raw material previously imported, was about 140,000,000*l.*,[1] then it would appear that if the same range of values had continued the check to the growth of this trade would have been that at the end of ten years the British labour represented in it instead of having increased 50 per cent., viz., from 140,000,000*l.* to 210,000,000*l.*, would have increased one-third only, or from 140,000,000*l.* to about 187,000,000*l.* The annual difference to the energy of the

[1] See my *Essays in Finance*, 1st series.

country developing itself in the foreign trade would on this showing be about 23,000,000*l.* only, an insignificant sum compared with the aggregate income of the people of the country; while the country, it must be remembered, does not lose the whole of this sum, but only the difference between it and the sum earned in those employments to which those concerned have resorted, which again may be a *plus* and not a *minus* difference. Even therefore if foreign competition is the cause of a check to our general growth, yet the figures we are dealing with in our foreign trade are such that any visible check to that trade which can have occurred must have been insufficient to cause that apparent diminution in the rate of our material growth generally which has to be explained.

It has to be remembered, moreover, that when the figures are studied and the fall of prices allowed for it is not in our foreign trade that any check worth mentioning seems to have occurred at all. The diminution in the rate of increase in the movements of shipping is very largely to be accounted for in the way already explained, viz., by the fact that the increase just before 1875 was largely owing to the multiplication of lines of steamers, and that a framework had then been provided up to which the traffic has since grown. Even an increase of one-third in the movements in the last ten years may thus show as great an increase in real business as an increase of 50 or 60 per cent. in the movements in the twenty years before. Foreign competition, even from natural causes, is thus insufficient to account for the diminution in the rate of increase of our material growth in the last ten years.

These figures may be put directly another way. The increase of our foreign exports per head between 1860–64 and 1870–74 was from 4*l.* 14*s.* 11*d.* to 7*l.* 7*s.* 5*d.*, or about 55 per cent., and allowing for an average rise of prices between the two dates may be put as having been at the extreme about 50 per cent. Between 1870–74 and 1880–84 instead of an increase there is a decrease, viz., from 7*l.* 7*s.* 5*d.* to 6*l.* 12*s.* 9*d.*, but deducting about one-third from the former figure for the fall in prices, the real increase in the last ten years would appear to be as from 4*l.* 16*s.* 3*d.* to 6*l.* 12*s.* 9*d.*, or over 35 per cent. The difference in the rate of increase in the last ten years compared with the previous ten is thus the difference between 35 and 50 per cent. only, equal to about 21,000,000*l.* annually on the amount of 140,000,000*l.*, assumed to represent the value of British industry in our foreign exports, deduction being made for the value of raw material included. A deduction of this sort from the annual income of the country is too small to account for such a check to the rate of our growth generally as that we are now discussing as probable, especially when we recollect that the labour is only diverted, and it is not the whole 21,000,000*l.* that is lost, but only the difference between that sum and what is otherwise earned, which may even be a *plus* and not a *minus* difference.

To bring the matter to a point, an increase of 40 per cent. in the income of the country in ten years would on an assumed income of 1,000 millions only in 1875, and the figure must then have been more, have brought the income up to 1,400 millions; an increase of 20 per cent. would have brought it up to 1,200 millions only, a difference of 200 millions, which must have arisen from the alleged difference in the rate of our material growth in question if it had occurred. Clearly nothing can have happened in our foreign trade to account for anything more than the smallest fraction of such a difference. The figures are altogether too small. We may repeat again then that it is not the check to our foreign trade which foreign competition may have caused to which we can ascribe the recent check to our general rate of growth.

I need hardly add that in point of theory foreign competition was not likely to have the effect stated. I have set forth elsewhere in an elaborate essay [1] the reasons for holding this opinion; why it is, in fact, that as foreign nations grow richer we should be better off absolutely than if they were to remain poor, though relatively they might advance more than we do. But, whatever theory may say, in point of fact the check to the rate of our material growth cannot, for the reasons stated, have been due to anything which has happened to our foreign trade.

[1] See my *Essays in Finance*, 2nd series, 'Foreign Manufactures and English Trade.'

Another explanation which has been suggested, and to which I have myself been inclined to attach considerable weight as being plainly, as far as it goes, a *vera causa*, is the extent to which the hours of labour have been reduced in many employments in consequence of the improvement in the condition of the working classes in the last half-century, and the growth of a disposition to take things easier, which has been the result of the general prosperity of the country. Such causes when they exist, and when they are brought into operation, must tend to diminish the rate of material growth in a country as compared with a period just before when they were not in operation. If we could suppose them brought into operation suddenly, all other things, such as the progress and development of invention, remaining the same, such a reduction of hours of labour and growth of a disposition to take things easy, must produce a check to the former rate of growth.

After some consideration, however, although there is no doubt of the general tendency of the causes referred to, I begin to doubt whether they would explain adequately such a check to the rate of material growth generally throughout the country as is assumed to have occurred. As regards the shortening of the hours of labour, which is the more definite fact to be dealt with, it cannot but be observed that the shortening has by no means been universal. It has been conspicuous among certain trades organised into trades unions; but the unions, after all, only include about a tenth part of the labour of the country. There has been no such conspicuous shortening of the hours of labour among professional men, clerks, domestic servants, and many others whose labour is an essential part of the general sum total. Next—and this is perhaps even more important—the shortening of the hours of labour is not coincident with the beginning of the last ten years, though it has been in full operation for the whole of that period, but rather with the beginning or middle of the previous ten years, viz., 1865–75; so that it should have been fully in operation upon the production of 1875; and the check to our rate of growth if due to this cause should thus have been felt between 1865 and 1875, rather than between the latter date and the present time. The same with the general disposition to take things easy. This disposition did not spring up in a day in 1875, but was probably as effective as a cause of change in the earlier, as in the later, period. It must count for something as a cause of the annual production of the country being less at a given moment than it would otherwise be; but in comparing two periods what we have to consider is whether the growth of this disposition has been greater in one period than in another; and there are no data to support such a conclusion as regards the last ten years compared with the previous ten.

We must apparently, therefore, reject this explanation also. It is not adequate to account for the apparent change that has occurred in the rate of our growth from the year 1875 as compared with the period just before. Our progress in periods previous to 1875 took place in spite of the operation of causes of a similar kind which were then in operation, and there is no proof at all that the shortening of the hours of labour and the growth of a disposition to take things easy have been greater since 1875 as compared with the period just before than they were between 1865 and 1875 as compared with the period just before that. What is wanted is a new cause beginning to operate in or about 1875, and the shortening of the hours of labour and the growth of a disposition to take things easy do not answer that description sufficiently. Something of the apparent change may be due to an acceleration in recent years of the growth of a disposition to take things easy, but on the whole the explanation halts when we make a strict comparison.

Another cause which may properly be assigned as a *vera causa* of a check to the rate of material growth in the country is the unfavourable weather to agriculture and the generally unprofitable conditions of that industry in recent years. *Pro tanto* such influences would make agricultural production less to-day than it would otherwise be. Employment in that industry would also be diminished comparatively, and perhaps absolutely, and a check to production generally would take place while labour was seeking new fields. But the check arising in this manner, as far as the general growth is concerned, has obviously not been very great. More land in proportion has been turned into permanent pasture, but very little land has gone out of cultivation altogether, and even the amount under the plough

has not much diminished. Agricultural labour, in somewhat greater proportion than before, has been obliged to seek other employments; the flow of population from country to town has been increased somewhat; but nothing new has happened to diminish production generally to a serious extent, and it is a new cause, it must be remembered, for which we are seeking. As far as unfavourable weather is concerned, again, that is only a temporary evil. One year with another, the weather is not worse now than at any former time; the remarkably unfavourable weather which lasted from 1874 to 1880 has passed. The other conditions unfavourable to agriculture, especially foreign competition, are more enduring; but these seem much more unfavourable to rent than to production itself, which is the point now under consideration; and we do not know that they will be permanent at all when prices and wages are fully adjusted.

The disturbance to industry by the fall of prices generally is also a *vera causa* of a check to the rate of material growth. But the effect of such a cause seems to be confined within narrow limits, and it is not a new cause. It occurs in every time of depression due to discredit, being partly the effect and partly the cause of the depression itself. All that is new recently is the extreme degree of the fall, and I must express the greatest doubt whether a mere difference of degree aggravates materially the periodical disturbance of industry, tending to check production, which a fall of prices from a high to a low level causes. So far as past experience has gone, at any rate, no such cause has been known to check production to any material extent. If any such cause tended to have a serious effect we should witness the results every time there is a shrinkage of values owing to the contraction and appreciation of an inconvertible paper currency, and I am not aware of any such contraction having had the effect described on production, though the effect in producing a feeling of depression is beyond all question. The facts as to the great contraction in this country between 1815 and 1820 are on record, while the experience of the United States after the civil war is also fresh in everyone's recollection. Contraction of currency and fall of prices, though they are painful things, do not stop production materially.

Another explanation suggested is that there is in fact no antecedent reason for supposing that the rate of material growth in a community should always be at the same rate—that a community may, as it were, get 'to the top' as regards its development under given conditions, and then its advance should be either less rapid than it had been or it should even become stationary. The defect of this explanation is that it assumes the very thing which would have to be proved. Is there any other sign except the alleged check to the rate of our material growth itself that in or about the year 1875 this country got 'to the top'? It has, moreover, to be considered that on *à priori* grounds it is most unlikely a community would get to the top *per saltum,* and then so great a change should occur as the apparent change we are considering. The persistence of internal conditions in a given mass of humanity is a thing we may safely assume, and if these conditions are consistent with a given rate of development in one period of ten years, it is most unlikely that, save for an alteration of external conditions, there would be another rate of development in the succeeding ten years. Human nature and capacities do not change like that. Scientific opinion, I believe, is also to the effect that the progress of invention and of the practical working of inventions, which have been the main cause of our material growth in the past, have been going on in the last ten years, are still going on, and are likely to go on in the near future, at as great a rate as at any time in the last fifty years. Except, as already said, the apparent check to the rate of our material growth itself, there is no sign anywhere of our having got to the top, so that a stationary condition economically, or a condition nearly approaching it, has been reached.

Last of all, it is urged that the diminution in the rate of material growth, which is in question, must be due to the fact that we are losing the natural advantages of coal and iron which we formerly had in comparison with the rest of the world. This is perhaps only another way of saying that we have got to the top by comparison, though the community of nations generally has not got to the top, and another way of saying also that foreign competition affects us more than it formerly did; an

argument already dealt with. But the question whether coal and iron at home are really so indispensable to our material growth as is sometimes assumed appears itself so important that I may be excused for specially discussing this question, notwithstanding that it has virtually been disposed of, as far as any explanation of past facts is concerned, by what has been already said.

The argument proceeds on the supposition—which is no doubt well founded in the abstract and as far as the past experience of mankind is concerned—that in addition to natural capacities of its own a community requires for its prosperity certain natural advantages: fertility of soil, rich and easily worked mines, a genial climate in which labour may conveniently be carried on, and so forth. A community possessing all these things, or the like things, will flourish, but as it begins to lose any of them its prosperity must become precarious, and population must flow to the places where they can be secured. Of course climate is not a thing which changes, as far as any practical experience is concerned; but relatively the advantage of a fertile soil may be lost, as England has lately lost it in comparison with the United States and other new countries, its soil having become inadequate for the whole population; and still more the advantage of mines, especially mines of coal and iron, on which the miscellaneous industries of a manufacturing country depend, may be lost. Hence, it is said, the check to our rate of growth in recent years. We have long since lost our agricultural advantages by comparison. Now we are also beginning to lose the special advantages which coal and iron have given. Our mines are becoming less rich than those of foreign countries, and the balance is turning against us. Why should not population relatively flow from England to the United States and other countries as it has passed within the limits of the United Kingdom itself from Cornwall and Sussex to Staffordshire, Lancashire, Yorkshire, and the north? In this view the coal famine of 1873 was the sign of a check such as Mr. Jevons anticipated. What has happened since is only a sequence of the like causes.

I need not repeat in opposition to this view what has already been said as to the inadequacy of any actual decline in our foreign trade to account for such a check to our general growth as is supposed to have occurred. If the loss of our natural advantages of coal and iron in addition to agriculture are having the effects supposed, we ought to witness them in our foreign trade, and in fact we do not witness them to the extent required for the production of the phenomenon in question.

What I wish now specially to urge is that in consequence of the progress of invention and the practical application of inventions in modern times the theory itself has begun to be less true generally than it has been. It is no longer so necessary, as it once was, as in fact it always has been until very lately, that people should live where their food and raw materials are grown. The industry of the world having become more and more manufacturing and, if one may say so, artistic, and less agricultural and extractive, the natural advantages of a fertile soil and rich mines are less important to a manufacturing community than they were at any former period of the world's history, because of the new cheapness of conveyance. Under the new conditions, I believe it is impossible to doubt, climate, accumulated wealth, acquired manufacturing skill, concentration of population become more important factors than mere juxtaposition to the natural advantages of fertile soil and rich mines. The facts seem at any rate worth investigating, judging by what has happened in England and other old countries in the last half-century and by what is still happening there.

Take first the question of food. Wheat is now conveyed from the American Far West to Liverpool and London and any other ports in the Old World for something like five shillings per quarter—equal to about half a farthing on the pound of bread, or a halfpenny on the quartern loaf. The difference between the towns of a country with fertile soil, therefore, and the towns of a country with inadequate soil is represented by this small difference in the price of bread. At about fivepence the quartern loaf the staff of life may be about 10 per cent. cheaper in the fertile country than it is in a country which does not grow its own food at all, and which may be thousands of miles away. As the staff of life only enters into the expenditure of the artisan to the extent of 20 per cent. at the outside, and

into the expenditure of richer classes to a smaller extent, the difference on the whole income of a community made by their living where the staff of life would be cheaper would be less than 2 per cent.—too small to tell against other advantages which may be credited to them. What is true of wheat is even more true of meat and other more valuable articles of food where the cost of conveyance makes a less difference in the proportionate value of the food *in situ* and its value at a distant point. The same more and more with raw materials. Cotton and such articles cost so little to transport that the manufacturing may as well go on in Lancashire or any other part of the Old World as *in situ* or nearly *in situ*; and even as regards metals or minerals, except coal and perhaps iron, the same rule applies, the cost of conveyance being as nothing in proportion to the value of the raw material itself. As regards coal and iron, moreover, there are many places where they are not in absolute juxtaposition, and if they have to be conveyed at all they may as well be conveyed to a common centre. Iron ore and iron at any rate are beginning to be articles of import into the old countries of Europe to which the cost, in fact, offers very little difficulty. The additional cost to the miscellaneous manufacturing of a country through its having to bring iron and coal from a distance may thus be quite inconsiderable, and apparently is becoming more and more inconsiderable. As regards raw materials generally it has also to be considered that, owing to their immense variety, there is an undoubted convenience in a common manufacturing centre to which they can be brought. Hitherto they may have come to England and other old countries of Europe in part because coal and iron were abundant there in juxtaposition; but the habit once set up, there seems no reason why they should not concentrate themselves on the old manufacturing centres. The ruder parts of the coal and iron industry may be attracted to other places, but the higher branches of manufacturing will be at no disadvantage if carried on at the old centres.

On the other hand, the old centres will retain the advantages, which are obviously very great, of climate, accumulated wealth, acquired skill, and concentration of population. That population under the new conditions is to go from them merely because they do not grow food which can be transported to them at the cost of a mere fraction of the aggregate income, and because they have not coal and iron in abundance and in juxtaposition, that abundance and juxtaposition, owing again to the diminished cost of conveyance, being no longer so indispensable as it was to the higher branches of manufacturing, appears certainly to be a 'large order.' What I have to suggest most strongly at any rate is that the advantages I have spoken of as possessed by old manufacturing centres are not unlikely to tell more and more under the new conditions, and that the indispensability of coal and iron is no longer to be spoken of as what it has been in the last century, during which apparently England owed so much of its precedence in manufacturing power to these causes.

To the same effect we may urge the specially great increase of the efficiency of coal in recent years. Cheap coal *in situ* cannot be relatively so important as it was in days when five or ten tons of coal were required to do the work which can now be done by one.

The truth is that the whole change that has been occurring is only a continuation of much larger historical changes. There has almost always in English history been some one industry that was supposed to be king. In the middle ages it was the growth and export of raw wool; last century it was the woollen manufacture itself; early in this century and down to a very late date cotton was king; more lately, since the beginning of the railway and steamship era, it has been coal and iron. How do we know, how can we know, that coal and iron are to reign indefinitely, any more than wool, or the woollen manufacture, or cotton themselves have done? Changes are always going on, and for that reason I believe we should attach the more importance to the increasing signs that it is no longer necessary or indispensable for prosperous communities to live where their food and raw materials are grown—that there may be advantages of climate, of accumulated wealth, of acquired skill, of concentration of population which are now, under the new conditions, overwhelmingly more important. It would be

absurd to dogmatise in such a matter. I hope, however, I have said enough to those who care to reflect to satisfy them that the indispensability even of coal and iron to the continuance of our material growth is no longer to be assumed, that there are wholly new conditions to be considered.

To come back to the practical point in all this discussion. Not only is there no sign in anything that has yet happened that the apparent check to our former rate of material growth is due to the loss of natural advantages which we once possessed, but the theory of natural advantages itself requires to be revised. Equally in this way as in the other ways that have been discussed, it is impossible to account for the apparent check to the former rate of our material growth which has been observed.

Having carried matters so far, however, and having found the insufficiency of the various causes which have been assigned for the check to our former rate of material growth, because they have not produced the sort of effect in detail which they ought to have produced so as to lead to the general effect alleged, or because they existed quite as much when the rate of growth was great as in recent years when a diminution has apparently been observed, it would seem expedient to inquire whether, in spite of the accumulation of signs to that effect, the apparent check to our rate of growth may, after all, not be a real one. To some extent I think we must conclude that this is the case. There are other facts which are inconsistent with a real and permanent check such as has been in question, and a general explanation of the special phenomena of arrest seems possible without supposing any such real check.

The first broad fact that does not seem quite reconcilable with the fact of a real diminution of the kind alleged in the rate of material growth generally is the real as distinguished from the apparent growth of the income tax assessments when allowance is made for the fall of prices which affect, as we have seen, all aggregate values. Assuming the fall of prices to be about 20 per cent., then we must add one-fourth to the assessments in 1885 to get the proper figure for comparison with 1875. The total of 631 millions for 1885 would thus become 787 millions, which is a falling-off of 35 millions, or 4 per cent. only, from the figure of 822 millions, which should have been reached if the rate of growth had been the same between 1875 and 1885 as between 1865 and 1875. Allowing for the raising of the lower limit of the income tax in the interval, this is really no decrease at all.

Of course this comparison may be thrown out if we are to assume the difference made by the fall of prices on the income tax assessments to be 15 or 10 per cent. only, instead of 20 per cent. But a point like this would involve a most elaborate discussion, for which this address would hardly be the occasion. I hope to find a better opportunity shortly in a continuation of my essay of ten years ago on the Accumulations of Capital in the United Kingdom. There is no doubt, however, that an allowance must be made for the difference of prices, and when any such allowance is made the rate of material growth would not appear to be so very much less between 1875 and 1885 than in the period just before, as it does in the above figures.

Another broad fact not easily reconcilable with the fact of a great diminution in the real rate of material growth in the last ten years is the steadiness of the increase of population and the absence of any sign, such as an increase in the proportion of pauperism, indicating that the people are less fully employed than they were. The increasing numbers must either be employed or unemployed, and if there is an increase in the proportion of the unemployed the fact should be revealed in the returns of pauperism somehow. The existence of trade unions, no doubt, prevents many workmen coming on the rates who might formerly have done so, but there are large masses of workmen, the most likely to feel the brunt of want of employment, to whom this explanation would not apply.

What we find, however, is that population has increased as follows: between 1855 and 1865 from 27,800,000 to 29,900,000, or $7\frac{1}{2}$ per cent.; between 1865 and 1875 from 29,900,000 to 32,800,000, or nearly 10 per cent.; and between 1875 and 1885 from 32,800,000 to 36,300,000, or over 10 per cent. If it is considered

that the figures are not fairly comparable for the early period, owing to the specially large emigration from Ireland, which took away from the apparent numbers of the United Kingdom as a whole, but still allowed of as great an increase in the manufacturing parts of the country as there has been later, then we may take the figures for England only, and what we find is—between 1855 and 1865 an increase from 18,800,000 to 21,100,000, or 12½ per cent.; between 1865 and 1875 from 21,100,000 to 24,000,000, or nearly 14 per cent.; and between 1875 and 1885 from 24,000,000 to 27,500,000, or 14½ per cent. Whether, therefore, we take the figures for the United Kingdom or for England only, what we find is a greater increase of population in the last ten years than in either of the previous decades when the rate of material growth seemed so much greater. If there had been such real diminution in the rate of material growth, ought there not to have been some increase in the want of employment and in pauperism to correspond?

It is one of the most notorious facts of the case, however, that there has been no increase, but instead a very steady decrease of pauperism, excepting in Ireland, which is so small, however, as not to affect the general result. As regards England the figures are very striking indeed. The average number of paupers and proportion to population have been as follows in quinquennial periods in England since 1855:—

	Number of Paupers	Proportion to Population per Cent.
1855–59	895,000	4·7
1860–64	948,000	4·7
1865–69	962,000	4·5
1870–74	952,000	4·2
1875–79	753,000	3·1
1880–84	787,000	3·0

Thus there has been a steady diminution in the proportion to the population all through, accompanied by a diminution in the absolute numbers between 1865–69 and 1875–79, though there has since been a slight increase. In spite of all that can be urged as to a more stringent poor-law administration having made all the difference, it is difficult to believe that a real falling-off of a serious kind in the rate of our material growth in late years as compared with the period just before should not have led to some real increase of pauperism. Change of administration may do much, but it cannot alter the effect of any serious increase in the want of employment in a country.

The corresponding figures as to Scotland are much the same:—

	Number of Paupers	Proportion to Population per Cent.
1855–59	123,000	4·2
1860–64	125,000	4·2
1865–69	131,000	4·3
1870–74	123,000	3·7
1875–79	103,000	2·9
1880–84	100,000	2·7

Here there is the same steady diminution in the proportion of pauperism to population all through as we have seen in the case of England, accompanied in this case by a steady diminution of the absolute number of paupers since 1865–69. The Scotch administration has been totally independent of the English, but the same results are produced.

In Ireland, as already hinted, the history has been different. There has been an increase in the pauperism accompanied by a decline of population. But Ireland is too small to affect the general result.

We are thus confronted by the fact that if there had been a real check of a serious kind to the rate of our material growth in the last ten years as compared with the ten years just before, there ought to have been some increase in the want of employment and in pauperism, but instead of there being such an increase there is a decline. The population apparently, while increasing even more rapidly in the

last ten years than before, has been more fully employed than before. To make these facts consistent with a check to the rate of our material growth we must contrive some such hypothesis as that employment has been more diffused as regards numbers, but the aggregate amount of it has fallen off: another form of the hypothesis as to the effect of shorter hours of labour already discussed; but a little reflection will show that any such hypothesis is hardly admissible. It is difficult to imagine any change in the conditions of employment in so short a time which would make it possible for larger numbers to be employed along with a diminution in the aggregate amount of employment itself.

Another fact corresponding to this decrease of pauperism is the steady increase of savings bank deposits and depositors. These deposits are not, of course, the deposits of working classes only, technically so called. They include the smaller class of tradesmen and the lower middle classes generally. But, *quantum valeant*, the facts as to a growth of deposits and depositors should reflect the condition of the country generally in much the same way as the returns of pauperism. What we find then is, as regards deposits, that the increase between 1855 and 1865 was from 34,300,000*l.* to 45,300,000*l.*, or about one-third; between 1865 and 1875 from 45,300,000*l.* to 67,600,000*l.*, or about one-half; and between 1875 and 1885 from 67,600,000*l.* to 94,053,000*l.*, or just about 40 per cent.—a less increase than in the previous ten years, but not really less, perhaps, if allowance is made for the fall of prices in the interval, and in any case a very large increase. Then, as regards depositors, what we find is an increase between 1855 and 1865 from 1,304,000 to 2,079,000, or 59 per cent.; between 1865 and 1875 from 2,079,000 to 3,256,000, or 56 per cent.; and between 1875 and 1885 from 3,256,000 to over 5,000,000, or over 50 per cent. Whatever special explanations there may be, facts like these are at least not inconsistent with a fuller employment of the population in the last ten years than in the previous ten.

Yet another fact tending to the same conclusion may be referred to. The stationariness or slow growth of the income tax assessments in general in the last ten years, as compared with the rapid increase in the ten years just before, has already been referred to as one of the signs indicating a check in the rate of advance in our material growth. But when the returns are examined in detail there is one class of assessments, more significant, perhaps, than any, of the general condition of the nation, viz., houses, which is found to exhibit as great an increase in the last ten years as in the previous decade. Between 1865 and 1875 the increase in the item of houses in the income tax assessments in the United Kingdom was from 68,800,000*l.* to 94,600,000*l.*, or just about 37 per cent. In the following ten years the increase was from 94,600,000*l.* to 128,500,000*l.*, or just about 36 per cent. In 'houses,' then, as yet there is no sign of any check to the general rate of the material growth of the country. Allowing, in fact, for the great fall in prices in the last ten years, the real increase in houses would seem to have been more in the last ten years than in the ten years just before.

Other facts, such as the increase of Post Office business, may be referred to as tending to the same conclusion. But there is no need to multiply facts. If no hypothesis is to be accepted except one that reconciles all the facts, then these facts as to the increase of population, diminution of pauperism, increase of savings bank deposits and depositors, increase of houses must all be taken into account, as well as those signs as regards production and other factors, which have usually been most dwelt upon in discussing the question of the accumulation of wealth and the material growth of the people. If the signs of a check to production in some directions can be reconciled with the fact of an unchecked continuance of the former rate of growth generally, then the later facts cited as to increase of population, diminution of pauperism, and the like, may be allowed to have their natural interpretation and to be conclusive on the point.

Such a general explanation, then, of the facts as to production in leading industries and the like, referred to in the earlier part of this address, consistent with the fact that there is no serious falling-off in the rate of our material growth generally, is to be found in the supposition that industry by a natural law is becoming more and more miscellaneous, and that as populations develop the dis-

proportionate growth of the numbers employed in such miscellaneous industries, and in what may be called incorporeal functions, that is, as teachers, artists, and the like, prevents the increase of staple products continuing at the former rate. This supposition, it will be found, has a good deal to support it in the actual facts as to industry and population in recent years.

The foreign trade shows some sign of the change that is going on. Looking through the list of export articles some remarkable developments are to be noticed. The following short table speaks for itself:—

Exports of the undermentioned Articles in the Years stated, with the Rates of Increase in 1855-65, 1865–75, *and* 1875–85 *compared.*

	Quantities exported				Increase per Cent.		
	1855	1865	1875	1885	1855-65	1865-75	1875-85
Candles, million lbs.	4	4	5·3	7·8	*Nil*	33	47
Cordage and twine, thousand cwts.	110	168	111	177	53	−34[2]	59
Plate glass, million sq. ft.	0·3	0·6	1·6	3·9	100	166	143
Jute yarn, million lbs.	not stated	4·9	15·9	30·7	—	224	93
Jute manufacture, million yds.	"	15·4	102·1	215	—	563	110
Iron hoops, sheets, &c., thousand tons	"	116	204	331	—	76	62
Tinned plates, thousand tons	"	63	138	298	—	119	116
Other wrought iron, thousand tons	"	214	239	348	—	12	45
Oil and floor cloth, million sq. yds.	0·5	2·4	6·3	11·3	380	162	79
Paper other than hangings, thousand cwts.	106[1]	145	319	733	37	120	130
Dressed skins and furs, millions	not stated	not stated	0·37	3·45	—	—	832
Soap, thousand cwts.	205	140	251	402	−32[2]	79	60
Spirits, million gals.	3·8	2·0	1·0	2·7	−47[2]	−50[2]	170
Unenumerated, values millions	—	—	£9·7	£10·6	—	—	10

Thus there are not a few articles, of which jute is a conspicuous example, in which there has been an entirely new industry established within a comparatively short period; and, though the percentage of increase may not in all be so great in the last ten years as in the previous ten just because the industry is so wholly new, yet the amount of the increase is as great or greater. In other articles, such as soap and British spirits, there is a new start in the last ten years after a decline in the previous periods. Such cases as oil and floor cloth, paper other than hangings, and plate glass are also specially noticeable as practically new trades. The list I am satisfied could be considerably extended, but I am giving it mainly by way of illustration. Finally, there is the item of other articles not separately specified—an item which is always changing in the statistical abstract because every few years one or more articles grow into sufficient importance to require separate mention, so that any extended comparison of this item for a long series of years is impossible. Still it is ever growing, and what we find in the last ten years is that, in spite of the fall of prices, the growth is from 9,700,000*l.* to 10,600,000*l.*, or nearly 10 per cent. Many of the articles referred to, it is plain, cannot run into much money, but the indications of a tendency are none the less clear. What is happening in the foreign trade is happening, we may be sure, in

[1] 1858 not separately stated before. [2] Decrease.

the home trade as well, of which in another way the increase in the imports of foreign manufactures, already referred to in another connection, is really a sign, as it implies the growth of miscellaneous wants among the consumers.

The census figures as to occupations tend, I believe, to confirm this observation as to the special growth of miscellaneous industries, but the discussion of the figures would require more preparation than I have had time for, and perhaps more space than can well be spared.

As to the growth of incorporeal functions, which is another fact significant of the supposed change in the direction of the employments of the people, I propose to appeal to the testimony of the census figures. I need refer on this head only to the paper read some time ago to the Statistical Society by Mr. Booth. Among those classes of population whose numbers in England and Wales in the last ten years have shown a disproportionate growth are the following:—

Numbers and Percentage of Self-supporting Population employed.

	Numbers		Percentage	
	1871	1881	1871	1881
Transport	524,000	654,000	4·9	5·6
Commercial Class	119,000	225,000	1·1	1·9
Art and Amusement	38,000	47,000	0·3	0·4
Literature and Science	7,000	9,000	—	0·1
Education	135,000	183,000	1·3	1·6
Indefinite	124,000	269,000	1·2	2·3
Total	947,000	1,387,000	8·8	11·9

Following the indication of these figures, whatever qualification they may be subject to, we are apparently justified in saying that an increasing part of the population has been lately applied to the creation of incorporeal products. Their employment is industrial all the same. The products are consumed as they are produced, but the production is none the less real. If a nation chooses to produce more largely in this form as it becomes more prosperous, so that there is less development than was formerly the case in what were known as staple industries, it need not be becoming poorer for that reason; all that is happening is that its wealth and income are taking a different shape.

It is quite conceivable, then, and is in truth not improbable, that a check to the former rate of material growth in certain directions may have taken place of late years without any corresponding check to the rate of material growth generally, which would seem to be inconsistent with such facts as the growth of population, diminution of pauperism, increase of houses, and the like. The truth would seem to be that with the growth of staple industries, such as cotton, wool, coal, and iron, up to a point, there being reasons for the remarkably quick development of each for many years up to 1875, there comes a growth of new wants, the satisfaction of which drafts a portion of the national energy in new directions. Just because certain staples developed themselves greatly between 1855 and 1875 the time was likely to arrive when they would grow not quite so fast. For the same reason the rapid increase for a certain period in the consumption per head of articles like sugar and tea was likely to be followed by a less rapid increase, the wants of consumers taking a new direction. Probably owing to the more and more miscellaneous character of modern industry, it will become more and more difficult to follow its development by dealing with staple articles only, while changes in aggregate values are untrustworthy as indications of real changes owing to changes in prices. Already there seems to be no doubt the staple articles are no longer a sufficient indication.

A supplementary explanation may be added which helps to explain another difficulty in the matter by which people are puzzled. I can imagine them saying

that it is all very well to pooh-pooh the non-increase or slower increase of the production of staple articles and to assume that industry is becoming more and more miscellaneous; but other countries go on increasing their production of these same staple articles. The increase of the manufactures of cotton, wool, coal, and iron in Germany and the United States, they will say, has in recent years been greater in proportion than in England, which is undoubtedly true. The explanation I have to suggest, however, is that the competition with the leading manufacturing country, which England still is, is naturally in the staple articles where manufacturing has been reduced to a system, the newer and more difficult manufactures and the newer developments of industry generally falling as a rule to the older country. Even in foreign countries, however, there are signs of slower growth of recent years in the staple articles as compared with the period just before. In Germany, for instance, the production of coal increased between 1860 and 1866 [I take the years which I find available in Dr. Neumann Spallart's 'Uebersichten'] from 12,300,000 tons to 28,200,000, or nearly 129 per cent.; between 1866 and 1876 the increase was from the figure stated to about 50,000,000 tons, or about 77 per cent. only; between 1876 and 1885, another period of ten years, from the figure stated to 74,000,000 tons, or less than 50 per cent.—a rapidly diminishing rate of increase. In the United States of America the corresponding figures for coal are 15, 22, 50, and 103 million tons, showing a greater increase than in Germany, but still a rather less rate of increase since 1876 than in the ten years before. The experience as to the iron production would seem to be different, the increase in the United States and Germany having been enormously rapid in the last ten years; but I have not been able here to carry the figures far enough back for comparison. Still the facts as to coal in Germany are enough to show how rapidly the rate of increase of growth may fall off when a point is reached, and that the experience of the United Kingdom is by no means exceptional. As the staple articles develop abroad the rate of increase in such articles will diminish too, and foreign industry in turn will become more and more miscellaneous.

The conclusion would thus be that there is nothing unaccountable in the course of industry in the United Kingdom in the last ten years. In certain staple industries the rate of increase has been less than it was in the ten years just before, but there would seem to have been no increase or little increase in the want of employment generally, while there is reason to believe that certain miscellaneous industries have grown at a greater rate than the staple industries or have grown into wholly new being, and that there has also been some diversion of industry in directions where the products are incorporeal. These facts also correspond with what is going on abroad, a tendency to decline in the rate of increase of staple articles of production being general, and industry everywhere following the law of becoming more miscellaneous. Abroad also, we may be sure, as nations increase in wealth the diversion of industry in directions where the products are incorporeal will also take place. What the whole facts seem to bring out, therefore, is a change in the direction of industry of a most interesting kind. If we are to believe that the progress of invention and of the application of invention to human wants continues and increases, no other explanation seems possible of the apparent check to the rate of material growth which seems to be so nearly demonstrated by some of the statistics most commonly appealed to in such questions.

At the same time I must apply the remark which I applied at the earlier stage to the opposite conclusion that there had been a real check to the rate of increase in our material growth. When the main statistics bearing on a particular point all indicate the same conclusion, it is not difficult to reason from them and to convince all who study them; but when the indications are apparently in conflict it would be folly to dogmatise. I have indicated frankly my own opinion, but I, for one, should like the subject to be more fully thrashed out. It is a very obvious suggestion, moreover, that one may prove too much by such figures—that it is an outrage on common sense to talk of there being no check to the rate of growth in the country when times are notoriously bad and everybody is talking of want of profit. What I should suggest finally, by way of a hypothesis reconciling all the facts, would be that probably there is some check to the rate of material growth

in the last ten years, though not of the serious character implied by the first set of figures discussed; that this check may even be too small to be measured by general statistics though it is sufficient to account for no small amount of *malaise*; and that the *malaise* itself is largely accounted for, as I have suggested on a former occasion, by the mere fall of prices, whatever the cause, as it involves a great redistribution of wealth and income, and makes very many people feel poorer, including many who are not really poorer, but only seem so, and many who are really richer if they only allowed properly for the increased purchasing power of their wealth. All these facts are quite consistent with the fact of a very slight real diminution in the rate of our material growth generally, and with that change in the direction of the national industry, significant of a general change beginning throughout the world which would seem to have occurred.

To some extent also it ought to be allowed that the tendency in the very latest years seems unsatisfactory, and that the developments of the next few years should be carefully watched. Up to now there is nothing really alarming in the statistics when they are analysed and compared. It may be the case, though I do not think it is the case, that causes are in operation to produce that great check and retrogression which have not as yet occurred, though many have talked as if they had occurred. The exact limits of the discussion should be carefully kept in mind.

Fortunately, however, there is no doubt what some of the conclusions on practical points should be. If it be the case that the hold of an old country like England on certain staple industries of the world is less firm than it was, and, as I believe, must be less and less firm from period to period, owing to the natural development of foreign countries and the room there is among ourselves for development in new directions, then we should make assurance doubly sure that the country is really developing in new directions. If our dependence must be on the new advantages that have been described, such as acquired manufacturing skill, concentration of population, and the like, then we must make sure of the skill and of the best conditions of existence for the concentrated population. If, in point of fact, shorter hours of labour and taking things easy have contributed to check our rate of progress slightly, there is all the more reason for improving the human agent in industry so as to make work in the shorter hours more efficient. Looking at the stir there now is about technical education and such matters, and the hereditary character of our population, I see no cause to doubt that the future will be even more prosperous than the past. The national life seems as fresh and vigorous as ever. The unrest and complaints of the last few years are not bad signs. But the new conditions must be fully recognised. The utmost energy, mobility, and resource must be applied in every direction if we are only to hold our own.

The following Papers were read :—

1. *Limited Liability.* *By* G. Auldjo Jamieson.

Growth of limited liability:

Either itself contributes to or is a symptom of widening of area of distribution of commercial and industrial profit.

Anticipations which heralded its adoption.

Royal Commission of 1853–54:

Diversity of opinion therein.
Report of majority adverse.
Legislation speedily sanctioned views of minority.
Diversity of opinion of witnesses.
Leaders of commercial world and representatives of mercantile centres adverse.
Alteration of law and adoption of limited liability advocated by lawyers.
Can now discern reason and significance of the diversity of opinion.

Principle of combination:

Characterised earlier commercial adventures and infancy of trade.
But allied with or accompanied by principle of monopoly.
Conflict between the ancient corporations and companies and individualism.
Conflict now probably waged under different conditions.
The many better able to assert right to share profits.
Combination of small adventurers rival to practical monopoly of vast individual wealth.
Yielding of the few to the many characteristics of the age. Levelling of eminences of commercial wealth. Great trade fortunes not now concentrated and transmitted intact, but distributed.

Limited liability at once aids and denotes this widening of the borders:

Affects favourably middle class by creating demand for skill, &c., apart from capital. Powers of initiation, superintendence, and direction differentiated from labour as well as capital.

Reasons of complaint against results of limited liability:

Failures conspicuous; successes attract no attention.
Growth necessarily slow.
Capacity for improvements—what are they to be?

Functions of the State necessarily preliminary:

These must be defined.
Power of State to grant incorporation.
Incorporation by royal charter.

Incorporation is act of creation:

Right of State as creator of incorporations to impress on them as its creatures characteristics necessary or expedient to public safety.
Limited liability implied by incorporation.
Logical extent of that limit; doubtful expediency of ultimate limitation as interpreted.

Parliament came to relief of Crown in granting incorporation:

Relation of State to companies not thereby affected.
Nor affected by general Act instead of separate Acts.

Limits of interference of State:

Must provide safeguards.
But abstain from direction or control.
Nor institute any preliminary inquiry implying sanction or approval.

What alterations in law regulating relations of State to companies necessary or expedient?

1. Memorandum of association may with advantage be made more flexible under sanction of Court.
2. Powers of borrowing must be regulated.
    In interest less of creditors than of shareholders and public.
    Unlimited powers of borrowing without precedent or analogy.
    Uncalled capital as fund of credit treacherous though more valuable than generally admitted.

Principle by which dividend paid on partially paid shares delusive:

Paid-up capital erroneously credited with profits due to uncalled liability.
That liability thus obscured and often ignored.
Proper method *interest* paid on capital paid up, and *profits* divided per share irrespective of amount paid.

Capital of trading companies might thus be from time to time reduced out of reserve or depreciation, and right to profits reserved to holders of shares thus paid off.

Paid-up capital and application thereof not sufficiently regarded by borrowers:

Position, stability, and success of company ought to be ground of credit, not uncalled liability alone.

Limitation of powers of borrowing:

Regard to be had to amount paid up as well as to amount uncalled.
Inexpedient to encourage borrowing to extent now prevalent.

Abortive and fraudulent companies:

Analogy of companies incorporated by charter or special Act.
Provisional registration accompanied by deposit liable to forfeit.
Probably to require more considerable fees on registration advantageous.
No company to be completely registered or to commence business with limited liability until specified proportion of its capital subscribed and paid up.

Compulsory publication of detailed accounts suggested, not expedient, probably unfair to skill and power of administration by exposure.

Reckless trading of limited companies:

Companies often go on long after an individual trader would stop.
Inexpedient in interest of shareholders, public, and traders.

Reserve liability: exigible only on liquidation, benefits direct and indirect.
Could thus dispense with Schedule B, at present virtually illusory.

Summary of suggested amendments:

I. Inception of Company.

1. Provisional registration: accompanied by deposit proportional to amount of capital.
2. Application for provisional registration to set forth.
   (1) Full names of promoters, directors, and officials with written evidence that they accept office.
   (2) Proportion of nominal capital to be subscribed and paid as condition of complete registration.
3. Complete registration.
   (1) Certificate to be lodged by all parties named in provisional register that minimum amount of capital subscribed, and stipulated proportion paid.
   (2) Registration to be complete only on issue of certificate that stipulations complied with and deposit then returned under deduction of *ad valorem* stamp duty.

II. Administration of Company.

1. Flexibility of memorandum by vote of large majority and sanction by court.
2. Powers of borrowing to be specified, and restricted with relation both to uncalled liability and to amount paid up.
3. Where shares not fully paid, interest only to be paid on capital actually paid up; but *dividend* to be made per share.

III. Winding up of Company.

1. Reserve liability to be allocated to every share of from 10 to 30 per cent. available only on winding-up.
2. No liability except that reserve to attach to shares duly transferred.
3. Liability for reserve to attach to holders of shares sold within a year of liquidation.

4. Creditors unpaid after certain period from date of liquidation to have right to apply to court to order levy on reserve liability from all parties liable, sufficient to pay all debts; equities between shareholders and parties thus levied on to be determined in liquidation; so that no creditor need wait issue of liquidation if reserve liability sufficient to pay debt.

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2. *The Economic Policy of the United States.*
By Professor LEONE LEVI, *F.S.S.*

FRIDAY, SEPTEMBER 2.

The following Report and Papers were read:—

1. *Report of the Committee on the methods of ascertaining and measuring Variations in the Value of the Monetary Standard.*—See Reports, p. 247.

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2. *Monetary Jurisprudence.* *By* S. DANA HORTON.

The author dealt with the nature of money, the present state of monetary knowledge, and the methods of enlarging that knowledge. Discussing the position of money in the sciences, he placed money on the border, partly in the field of economics and partly in that of jurisprudence, the latter being the controlling portion. The peculiarity of monetary jurisprudence was its partial extra-territoriality. The laws are of one State, the data in large measure belonging to the family of States; the individual wealth-maker, wealth-exchanger, wealth-consumer supplying the conditions in the midst of which the State acts. The mere name of monetary jurisprudence carried with it the recognition of the importance of history, for the education of a jurist is an education in the history of principles and of their application. The neglect of this double jurisdiction of monetary science explained the backwardness of its position to-day. The jurist cared little for economy; the economist little for law. A fashion of thought which grew up in the shadow of Adam Smith favoured that neglect. A proper utilisation of monetary history might therefore expect to dispel many of the difficulties of the subject. The world has been wont to forget much that it knew; but in the monetary field it is wont to forget it over and over again. It is necessary for science to accept the responsibilities of statesmanship, to deal with principles as well as with data—not only to inquire into the twisted bayonets and the officers responsible for them, but also into the system that produced the officers. The time that produces an address of such range as Dr. Giffen's, and an epoch-making report such as that just read, can afford to deal with the whole subject, and especially the higher portions of it—the duty of the State in the regulation of money. The author then gave illustrations of the extent to which history throws a light upon questions of principle. The first point illustrated was the popular antithesis between the artificial and the natural—an antithesis which goes to the root of the opposition between the political and the economic side of money. As an illustration of the instructive lessons which history could give, he instanced gratuitous coinage. Is it artificial or natural? The facts would show the fallacy of the current application of this antithesis to money. If anything was artificial, gratuitous coinage was artificial. By a law of gratuitous coinage the State gave a bounty to bullion-owners. And yet that had been the law of England for 220 years. What was the origin of that principle which the councillors of Charles II. introduced in an age when the seigniorial system was the rule of Christendom? He would read two quotations which stated the principle and reason of it and threw a light which would be looked for in vain in monetary literature of the nineteenth century. The

quotations were to the effect that 'at common law money ought to be of the same value, whether coined or not coined; hence the expense of coining should be borne by the public.' Whence came these words? They implied a subtle insight into the nature of money as a measure, and were parallel with the principle, old as, if not older than, the law of the Jews, that 'divers measures are an abomination to the Lord.' Those words were said three centuries before Charles II.'s time by the great interpreters of the Roman law to the Middle Ages—Baldus, Bartholus, the 'Glossators,' professors at Bologna and Pisa. A second illustration was the duty of the State touching the stability of the value of money. The demand that Government should interfere in that behalf had been spoken of as something new, something modern, something made for the present occasion, and therefore factitious and unsound. That was a contention which history alone could deal with. To dispose of it he would introduce to the disciples of Smith and Ricardo another ally, hitherto unknown, one of the great masters of thought of a date even earlier than Baldus and Bartholus. This was Thomas Aquinas. On consulting that great man on the point, he found it was his opinion that 'money ought to be so instituted or established that it may remain more stable in value than other things.' A comparison was then made between this opinion and that of Aristotle.

A third illustration related to the English authorities for the modern anti-silver laws of England. Lord Liverpool stood as the scientific sponsor for the origin of these laws, but upon examination it appeared that he regarded himself as basing his views upon the opinions of others. For him Sir Wm. Petty, John Locke, and Joseph Harris were the masters of English monetary thought. But what had they to do with anti-silver laws? History supplied the answer. Their ideas of monetary reform in a country which maintained the gratuitous coinage of silver and gold were limited to insisting that the silver pound should not be tampered with, and that gold should be properly rated in terms of silver. The alleged precedent against silver, against two metals, existed only in imagination or in belief based on error.

A fourth illustration dealt with Lord Liverpool himself, who in passing into history had been the object of what might be called an instance of modern myth-making. He had been regarded as the scientific expert and sponsor of the monetary system adopted in 1816. Research proves that this was an error. The system proposed by Lord Liverpool in 1805 was devoid of the important anti-silver features which gave the aggressively anti-silver character to England's actual system. Who, then, was the scientific sponsor of the law of 1816? He could not say; but it seemed probable the credit lay between the Hon. Wellesley Pole (Lord Maryborough) and Mr. John Wilson Croker. Lastly, the author referred to the battle of the standards, single standard against double standard, which had raged for a generation. The issue of the standards was a false issue in important respects. It implied a necessary opposition between the single standard and the double standard. There was no such necessity. The word 'standard' was a slippery place in the language, upon which millions slipped and fell. No one could escape who had not armed his soles with definition. Now definition was made practicable by history. Once it was understood that for centuries England had a single standard and a double standard at the same time (with its silver pound and rated guinea) the monetary stumbling-place of this generation would lose its terrors.

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3. *Some Notes on Money. By* Sir T. FARRER.

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4. *Changes in Real and in Money Prices. By* WYNNARD HOOPER, *M.A.*

Prices, though always stated in terms of money, for the purposes of economic inquiry, are regarded as of two kinds. The *real price* of an article is its value expressed in terms of all other commodities, including the precious metals. Its *money price* is its value expressed in money, that is, in terms of the precious metals only.

A. Changes in *real prices* are produced by alterations in the supply-and-demand relation of the commodities affected. There are eight possible cases of

change in this relation. In two of them the effect on prices is indeterminate. In two a rapid fall or rise, of short duration, is produced; and in four a fall, or rise, which may or may not be rapid, according to the character of the commodity, is produced. In the case of a necessary, such as wheat, the fall in case of an increase of supply, and the rise in case of a decrease, will be rapid because there is no desire to increase, and at the same time the greatest unwillingness to diminish the consumption of bread. A fall in wheat is 'taken out' in increased consumption of luxuries.

Changes in either component of the supply-and-demand relation of most articles usually affect the other by producing alterations in prices. This is especially true of *luxuries*. A 'luxury' might be defined as 'a commodity of which people would, if they could afford it, gladly obtain and consume much more than the supply available.'

Changes in the supply of a large class of articles are due partly to meteorological conditions, partly to the bringing of fresh portions of the earth under cultivation, or to their becoming more accessible, owing to the extension of steam communication.

Increase of demand, apart from changes in price, is chiefly due to increase of population.

Supply sometimes increases rapidly, owing to speculation, to an extent much exceeding atcual demand, and the increased supply is absorbed comparatively slowly.

B. Changes in *money prices* are due to changes in the supply-and-demand relation of the precious metals.

The total mass of the precious metals is *approximately constant*, owing to their durability. It does increase year by year, but the annual increment is usually small relatively to the total mass. Unless the supply is added to year by year, to an extent depending on the increase of the quantity of commodities in the world, the money prices of commodities will tend to fall. Market prices will not necessarily show any change, since real price may have moved in the opposite direction.

The demand for the precious metals is always strong, but is only indefinitely great as regards gold. Most countries would use gold if they could, but have to do without it. The natural bias in favour of gold, due to its peculiar qualities, is intensified by the desire of the poorer countries of the world to possess a gold standard, under the mistaken idea that such a standard will help them to grow rich, and also by the natural desire of bankers, who have great influence with Governments, that the standard of the country they live in should be the same as that of the United Kingdom. Germany and Italy have adopted gold standards for these reasons. They would have done more wisely if they had chosen silver. Italy has some difficulty even in keeping all the silver she needs, and puts restrictions on its free withdrawal.

Gold being the preferred currency of all the more advanced nations, changes in the supply-and-demand relation of gold are a more effective influence on money prices than changes in the supply-and-demand relation of silver. Gold changes work through a more powerful machinery. Nevertheless silver changes must not be disregarded. Even in silver-using countries money prices, and consequently market prices, are, to some extent, influenced by gold. And in like manner in gold-using countries prices are, to a smaller extent, influenced by silver.

If gold did not exist the silver in the more advanced countries would be a more potent influence on money prices than the silver in the less advanced countries.

Changes in money prices are small compared with changes in real prices.

The richer of the more highly organised countries have, at present, enough gold for their wants, but they have some difficulty in keeping it, as several of the poorer countries are making efforts to get it. The Bank of England, the chief storehouse of gold to which access is free, is often asked for it, and thus the bank's stock of bullion is kept down to about the *minimum* which is compatible with safety. All surplus gold is, on our system, placed in a position where it can be easily got at, since a very moderate excess in the bank's stock forces down the rate of discount.

Fresh supplies of gold would, in the first instance, come to London, but would very soon be exported to the countries which wish to increase their stock of it. If the increased supplies were continued on a large scale for several years a time would come when these demands would be satisfied. If no fresh countries decided to obtain gold, gold would begin to accumulate in the Bank of England, and then, and not till then, would money prices begin to be raised by the addition to the world's stock of the precious metals.

Changes in money prices are always an evil, and it is uncertain whether a rise or a fall is the worst. In any case attempts to alter them by Government interference are purely mischievous.

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5. *Graphic Illustrations of the Fall of Prices in Belgium, France, and England. By* Professor DENIS.

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6. *Effective Consumption and Effective Prices in their Economical and Statistical Relations. By* HYDE CLARKE, *F.S.S.*

The author began by defining that the present paper had no connection with his papers on prices and depression of prices consequent on the operation of industrial inventions, read before this Section and other societies. He had latterly been induced to call attention to the statistical discrepancies between the figures of the importation of commodities derived from the Board of Trade returns and those of actual consumption.

These discrepancies arose from the substitution for the imported commodity by the retailer of other commodities, perhaps of home production. Thus the figures of imports would not show the real consumption or the price which affected the consumers. A decrease of the import might not signify a diminished demand for the retail article. The same disturbance affects home production. If a town consumed and paid for 100,000 gallons of beer, it might be supplied with 100,000 gallons from the breweries, or 75,000 gallons from the breweries and 25,000 gallons of water substituted by the publicans. The consumers would pay the same, but the brewers would get money for 75,000 gallons only, and the publicans for 25,000 gallons besides their retail charges on 100,000 gallons. In the case of coffee, that consumed is sometimes the reverse of coffee, as it may consist of 90 per cent. of chicory, ground date and olive stones, &c., and only 10 per cent. of coffee. To ascertain the positive consumption of a working man it was not sufficient to assume that he had so many pounds of butter, beer, tea, coffee, &c., when a portion consists of water, butterine, chicory, bullock's liver, &c. The matter to be considered is not strictly adulteration in a sanitary sense, but the substitution of one article for another and the statistical consequences. The increased consumption of strong Indian tea has enabled the retailers to cover the substitution of inferior mixtures for tea. The purchasing power of the community has no immediate dependence on the conditions of importation, but rather on that of the article presented by the retailer. If coffee is retailed at 20*d.* a pound the value of the real coffee used may be 2*d.* and the whole cost of the article 3*d.* Consequently importation and consumption do not exactly represent each other. The author enumerated many articles which are subject to the operation of substitutes, including beer, spirits, wine, vinegar, tea, butter, tobacco, soap, bread, milk, pepper, mustard, oil. Water figures largely in the operation of substitution. Even in the case of tobacco the revenue authorities recognise added water to the extent of 33 per cent., so that a pound of tobacco may represent two-thirds weight of tobacco and one-third weight of water. Soaps may be made to absorb 40 per cent. of water. His purpose was to invite closer attention to retail consumption and prices as statistical bases.

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7. *The Battle between Free Trade and Protection in Australia. By* WILLIAM WESTGARTH.

A sleepless contest, more or less earnest and animated, goes on amongst our Australasian colonies on the merits respectively of free trade and protection. It should be premised that when the Imperial Government conceded constitutional self-government to these colonies, now rather over thirty years ago, they were all launched upon the general free trade basis of their mother's system. From that they have mostly more or less departed since, but in no case to any material extent excepting in that of Victoria, while her immediate neighbour New South Wales has continued faithful to free trade. As these two colonies, although by no means identical in circumstances, have, one thing with another, a fairly compensatory adjustment, the race of progress between them is extremely interesting, and that race will probably prove ere long a factor of decisive character in the general question. Although Victoria has not yet plunged very deeply into protection, the extent consisting chiefly in a somewhat general *ad valorem* duty of 25 per cent., with certain lesser rates, and a maximum of 30 per cent. upon woollen clothing, she would nevertheless appear, as statistics to be here quoted may show, to have so far encumbered her action as to be threatened with the second place in the closely competed race.

This contest has been very recently accentuated by two very able statements, one on the Victorian side for protection, the other on that of New South Wales for free trade. The first is in a series of articles in the 'Age' (March–April 1887), a Melbourne daily newspaper of leading position and large circulation—over 68,000 copies—and which has always been firm to protection principles; the other is the special reply to these articles on the part of Mr. Pulsford, the secretary to the New South Wales Free Trade Association. There are many expletives and epithets on either side to amuse the reader. Each marshals forth a client brimful of resource and progress. But while New South Wales permits freedom of trading, and Victoria restricts her exchange sphere in favour of certain industries, either advocate is equally sure that his own colony is on the best road.

New South Wales, which is now a century old, has had twice the length of life of Victoria, but beginning in a small way as a convict colony. There was not much comparative attainment in either case until in 1851 the great avalanche of gold-production precipitated all Australia into a nation, as the late Mr. Wentworth happily phrased it. The 'Age' writer claims that as New South Wales is four times larger than Victoria the former had in that respect four times the advantage. But as most of that larger area is of a sterile character, and fit only for pasture, while Victoria is a compact territory abounding in agricultural land, the wider area is, perhaps, for the present at least, rather a disadvantage. There are various *pro* and *con* data of this sort, such as that New South Wales has swelled her accounts of late years by larger land sales and more railway-making than Victoria; while, on the other hand, as being much more largely pastoral, she has more severely suffered during those years by the late severe drought. Altogether there may be a fair comparison by reference to the respective totals of population, revenue, and trade from a starting-point a few years before the gold discovery until the present time, and to the accumulated wealth respectively as the result of their different trading systems.

In commenting on these data, as given by the 'Age' writer, Mr. Pulsford points out a variety of errors in regard to New South Wales statistics, and particularly one of so enormous a character as completely to vitiate the 'Age' writer's chief argument. This is as to accumulated wealth as represented by ratable property in the two colonies, the 'Age' giving above 114 millions sterling for Victoria, and only 56 millions for New South Wales; while its opponent, from official documents, gives for the latter 197 millions. He confirms this statement by quoting the well-known statist Mulhall, who for 1883 gave property per head in Victoria as 198*l.*, while in New South Wales it was 241*l.* Towards explaining so great an error in one who seems otherwise both careful and discriminative in his facts there are allusions on either side to the effect that the statistical method of the one colony is,

in some cases, not quite clear to the other. Then comes the further and final test of population, trade, and revenue. To understand fully the two tables here given it is premised that Victoria started, relatively speaking at least, decidedly behind New South Wales, but that her enormous gold-production—at first ten times that of New South Wales—quickly sent her far ahead in all three items. Her gold, however, gradually fell off, until it is now but about three millions to the one million of the other colony. Victoria, then, with the spare labour from gold-digging, turned herself naturally to increased agriculture, and also, by means of protection, to manufactures. Meanwhile, New South Wales, inevitably distanced for a time by the Victorian gold, has since been gaining steadily on her sister, and is already equal in population and substantially ahead in trade and revenue.

SUB-SECTION F.

1. *Preventible Losses in Agriculture.*[1] *By* Professor W. FREAM, *B.Sc. F.L.S., F.G.S., F.S.S.*

In this paper losses in agriculture are classified under the two heads of controllable and uncontrollable. The latter are chiefly due to meteorological causes. The former are such as may be reasonably anticipated, and, therefore, provided against. The circumstance that they are tolerated at all is attributable partly to ignorance, partly to indifference, partly to empiricism.

Various sources of preventible loss are cited and discussed. Examples are—imperfect working of the soil; use of bad seed; encouragement of weeds; deterioration of grass lands; farm pests; diseases of livestock; injudicious purchases of artificial fertilisers and feeding stuffs.

As remedies for preventible losses, and therefore as means for rendering agriculture a more profitable industry, two courses are suggested: (1) the extension throughout the country of sound technical instruction in agriculture; (2) the equipment by the nation of a thoroughly efficient Department of Agriculture. These proposals are discussed at some length, and the practices of other countries are noticed.

The paper concludes as follows:—

A properly equipped Department of Agriculture could do much to stimulate agricultural inquiry and to promote agricultural prosperity in this country. Compared with other industries, agriculture is handicapped, inasmuch as its workers are more isolated, and have fewer opportunities of interchanging experiences, or ot attending meetings for discussion or other objects. The Department could keep agriculturists well instructed upon a variety of subjects, respecting which information is now acquired only in a haphazard manner. Upon statistical matters of current interest, upon impending crop scourges, upon the health of livestock, upon the much-needed reforms in dairy practice, it could and should elaborate and disseminate instruction and advice, and it would thus act as a powerful lever in the direction of better technical instruction in agriculture. The demand for an efficient Department of Agriculture is heard both in Parliament and in the shires; year by year it becomes more pressing, and the time cannot be far distant when it must be met.

It is estimated that about one-fourth of the inhabitants of the United Kingdom are dependent upon the agricultural industry. It is desirable, therefore, that this our leading productive industry should be encouraged and fostered in every legitimate way. I have endeavoured to indicate two of the directions in which improvement may be effected. At the same time I am aware that some economists would prefer to seek relief along other channels, and would, with this object, point perhaps to our national fiscal policy, to the incidence of local taxation, to the ques-

[1] Published *in extenso* in the *North British Agriculturist*, &c.

tion of rents, or to preferential railway rates. Without entering into these subjects I submit that improved technical agricultural instruction on the one hand, and an efficient Department of Agriculture on the other, are urgently needed. Of all the productive arts agriculture is, in this country, the least provided for as regards technical education, and it is a reproach to us, as a nation, that this should be so. The Rothamsted investigators, than whom I can quote no higher authority, assert ('Phil. Trans.' Part I. 1880, p. 290) that 'agriculture—the most primitive and commonly esteemed the rudest of arts—requires for the elucidation of the principles involved in its various practices a very wide range of scientific inquiry.' This means that in agriculture, as in all other progressive industries, empiricism must die.

Obviously the question before us is this, Is British agriculture, already by pessimists regarded as a moribund industry, really to be left to decay, with the deplorable but inevitable result of crowding the rural population into the towns; or is it, by a wise and enlightened policy, to be brought into harmony with the scientific spirit of the times, and so to be embarked upon a new era of profitable and progressive development?

2. *On the Future of Agriculture. By* W. Botly.

The author advocated a return to the scale of rents existing previous to the great French War, showing that the numerous committees, commissions, and Acts of Parliament had been delusive and useless in sustaining prices.

He considered the remedy for the lamentable depression to be an equitable adjustment of rents, tenant right, security of tenure, and compensation for all unexhausted improvements, whether to the outgoing or sitting tenant; decent cottages for the labourers, with garden ground attached thereto; the tenant to have sufficient capital to farm advantageously, with skill and enterprise to use it, and to have a right to the game.

3. *Recent Illustrations of the Theory of Rent, and their Effect on the Value of Land. By* G. Auldjo Jamieson.—See Reports, p. 536.

4. *On Depreciation of Land as caused by recent Legislation. By* Courtenay C. Prance.

The author pointed out that land had hitherto had a factitious value in England; that investors were content with a $2\frac{1}{2}$ or 3 per cent. return instead of 4 and 5 per cent. as in banks, railways, or mortgages. He found an explanation of this in the advantages and privileges which the possession of land brought with it: as for example, (1) it was a *visible* token of property and conferred a county status; (2) it was permanent and safe, having increased in value with lapse of time; (3) it had a sentimental value—it was pleasant to walk over, gratifying to show to friends and to admire as pictures; (4) it carried with it the right to sport; (5) it gave political power over voters; (6) power also in the parish charities and Poor Law relief, and was the qualification for the county magistrate; and (7) it was a means, by entails and settlements, to build up families, perpetuate names, and extend possessions.

These were some of the effective causes in rendering land a coveted possession and giving it an augmented value.

But this land-hunger was now gone. No longer are there competing purchasers or competing tenants. In proof of this the author referred to the advertisement columns of the *Times* and other newspapers now empty of estate sales, and said that at present to attempt sales of land by auction is merely throwing away money. That landlords were everywhere seeking tenants, not tenants farms, and too often seeking in vain. He referred to the Income Tax returns as to vacant farms, and to land out of cultivation, and to reduction of rents by 20 to 50 per cent. in order to avoid this. He substantiated this by a table of the 'Decrease of land asses-

ments under Schedule A' in twenty-two counties of England, varying from 256,000*l.* in York to 46,000*l.* in Devon. By Mr. Pryor's recent table as to 21,000 acres in Essex either out of cultivation or farmed by owners; and by Sir Jas. Caird's evidence before the Commission on the Depression of Trade, who, on the average of England, puts the landlords' loss at 30 per cent. of their spendable income, and the tenant's at 60 per cent. of his capital. He added further statistics of the value of the live and dead stock employed in farming, and from the gigantic figures resulting argued that the subject of the paper was well worthy the serious attention of Section F.

The paper then pointed out that while other causes had been at work and should not be overlooked, yet this depression and loss had been contemporaneous with recent land legislation, which had been directed to the abolition of those very rights and privileges which had formerly rendered the acquisition of land desirable, and the author thought it fair to connect such fall and depression with this legislation as cause and effect. He instanced—

1. The Repeal of the Corn Laws, which had flooded England with foreign corn and provisions.

2. The Repeal of the Navigation Laws, which had created a swift and cargo-bearing fleet, and raised the mercantile tonnage from 106,321 tons in 1850 to 3,889,000 tons in 1886, with a greatly reduced freight.

3. The Ballot Act, which took away the landlord's political influence, and other Acts abolishing landed qualification of the sportsman, the voter, the member of Parliament, the justice, and now (in contemplation) the sheriff.

4. New Burdens and Taxes saddled on the Land.—As (*a*) the succession duty under 16 & 17 Vic. c. 51, which produced, for the year ending March 1885, £935,053 14*s* 1*d.*; (*b*) abolition of turnpikes and throwing the highway repairs on country parishes, with statistics of expenditure; (*c*) rural sanitary Acts, rural police, lunatics, burial boards, &c.

5. The Ground Game Acts, which, giving hares and rabbits to tenants, have diminished landowners' pleasure and inducement to country residence.

6. The Bankruptcy Acts and Act lessening the right to distrain, which, though intended for the tenant's benefit, the author contended injured him and crippled his credit, particularly with his landlord and banker.

7. Lord Sandon's Education Act of 1876.—Education Boards have rapidly extended. In 1861 the accommodation was for 1,396,483 children, in 1885 for 5,658,819, is still increasing, and the expenses too. Allowing the propriety of every child having a good education, the author contended that the Act prejudicially affected land (*a*) by throwing an additional burden on it; (*b*) by abstracting boy labour from the farm; (*c*) by deteriorating the character of the labourer's child, making him dissatisfied with home and hard work, and anxious to be a clerk or shop assistant, and to dress fine.

8. State-aided Emigration, which takes away our best and most adventurous workmen.

9. The Agricultural Holding Act.—The author gave an explanation of its provisions; insisted that the farmer, who has the land let to him, has already power to protect himself, and that it is the landlord who, surrendering possession of an important and easily injured property, needs the protection. At all events, that the Act promises to be a fruitful source of litigation, and to again diminish the owner's interest in his possession.

The writer then passed on to consider *the results* of the present state of things. He thought these would be (*a*) an increasing disinclination to buy land; (*b*) a permanent fall in rents; (*c*) a lower style of farming, and less inclination and power in the landlords to assist their tenants; (*d*) a reduction of agricultural wages; and (*e*) a fall in the current rate of interest on mortgages, and then of other loans.

The paper concluded *by suggestions* as to improving the present state of things.

1. The author contended that the facts do not justify the present depression, that agriculturists are needlessly frightened. The American corn-grower is tired of growing at a loss, the wheat breadth is diminishing and going ever farther west. But the English farmer is not doing his best. He should get more from his land,

and remember he but shares the present fate of every profession and trade. Also that he now has all the necessaries of life cheaper than heretofore.

2. The hours and system of rural schools might be altered. After children attained ten they might have the mornings free, and the teaching be confined to afternoon, and spread over more years; and from thirteen to sixteen be distinctly agricultural and practical in its character.

3. The farmer himself wants training; English farming is 'Rule of Thumb,' there is little or no scientific knowledge or practice. He should make it a trade. Be careful for little things, value small profits, and shun small losses.

4. Existing depression should lead to landlords planting more timber, and to its more systematic culture. Government to find the first cost at 3*l.* per cent. interest. Orchard culture and combined dairies should be also followed out.

Lastly, the agricultural interest is so vast and so wide in its ramifications, that we may well insist on a Minister of Agriculture with under-secretaries who have, as a qualification, attended a full course in some agricultural college, and who shall also be owners of landed estates; these should keep an eye on all foreign and English agricultural statistics, and distribute them in accessible form; have, perhaps, travelling inspectors, and above all watch the legislation which is brought forward in the House of Commons, and preserve us from those measures which, however well-intentioned, are deleterious in their effects, and too often the crude ideas of doctrinaires who have never owned an acre of land or grown a sack of wheat.

5. *Land Tenure in Bosnia and the Herzegovina. By* Miss Irby.

By the Treaty of Berlin, 1878, Austria-Hungary undertook to administer the Turkish provinces of Bosnia and the Herzegovina in accordance with existing laws. Many of these laws, which remained a half-dead letter under Turkish rule, are admirable and worthy of our own consideration.

Passing over the Turkish definitions of the various kinds of land, and many interesting and disputed questions as to their historic origin, the paper proceeded to describe the actual and present conditions of landholding in Bosnia and the Herzegovina.

At this moment (in 1887) all land which is neither State property, nor Vakouf, *i.e.*, mosque property, nor common nor waste land is held on one or other of the three following tenures:—

1. As freehold property, by the owner farming it himself. 2. On simple lease. 3. On what is known in France, Spain, and Italy as the Metayer tenancy.

By the Metayer system the landlord, or *aga*, and the cultivator, or *kmet*, share the produce in kind in a proportion fixed by the custom of the district. The tenth, due to the Government, is paid in money previously by the kmet. The kmet, or tenant, cannot be ejected so long as he pays his dues and cultivates the land no worse than his neighbours. As the standard of cultivation is extremely low, this system renders the progress of agriculture very slow. It will take a long time for them all to improve together. But this system is invaluable in Bosnia, as preserving the very existence of the native population, who must be given time to improve. Here, as elsewhere, social and political interests do not appear at first sight to coincide, but justice is ever the best policy.

SATURDAY, SEPTEMBER 3.

The following Papers were read:—

1. *A Plan for County Councils. By* J. Taylor Kay.

The British political instinct has been largely in favour of local self-government, instanced in our earlier history by the number of boroughs and guilds

instituted by the people themselves, and in our later history by the settled systems of government immediately instituted by our colonists, and the sincere imitations exhibited by the people of the United States of America. Lately there is a growing tendency to centralisation in what may be termed the home departments of government, caused by the creation of many new local government areas and authorities since the Reform Bill of 1832, and all placed under imperial control. In counties there are now usually twenty-two different kinds of local government districts, controlled by the Privy Council, the Home Office, the Local Government Board, and the Board of Trade.

The Public Health Acts of 1872 and 1875 by the institution of the urban and rural sanitary authorities have indicated a remedy for these incongruous areas and authorities.

After indicating the authorities at present existing in counties and the methods of taxation in vogue it is proposed that county councils should be formed, to be constituted by the present justices of the peace in each county and five elected representatives from each urban and rural sanitary authority in their area; the urban authorities consisting of the town councils, the improvement commissioners, and the local boards of health, and the rural authorities of the representatives of the rural districts on the boards of guardians of the poor. A tabular view is submitted of the counties of England and Wales, with the number of urban and rural sanitary authorities in each and a comparison of the justices of the peace with the proposed number of elected representatives, together with the total number of members of the proposed county councils. Though apparently the justices would outnumber the elected representatives, this is only nominally so, as it is officially stated that about 80 per cent. of the justices must be deducted through repetitions (as being on the commission for more than one county), non-attendance through age, non-residence, &c. The existing state of things shows that the number of justices in each county and the number of the urban and rural sanitary authorities are very much in proportion to the extent, the financial importance, and the population of the areas, and the number of members of each council would of course vary in that proportion.

Such an arrangement would tend to unify county government and relieve the Imperial Legislature. The councils would take over the civil administration of the magistrates, the duties of overseers, the control of highways, county bridges, lunatic asylums, and county buildings, and the assessment, rating, and general financial arrangements. They would regulate the local administrative policy, the police, the licensing, and the poor-law systems, co-ordinating the general and municipal public health requirements of boroughs and rural districts, and formulating the exigencies of the School Board requirements of their areas. They would report to the Imperial Legislature on all private parliamentary Bills affecting their districts, public endowments, and charities, and submit a county budget. It is proposed that all magisterial functions should be placed in the hands of well-trained and well-paid lawyers. Thus outside the courts of law or judicial business they would, under the direction of the principles laid down by the Imperial Government, direct the local administration of their areas generally. The variety of procedure would bring out the differences of custom, usage, and political tendency. Questions of local option and other legislative measures of the utmost importance, upon which the time of Parliament is now annually spent without effect, would be tentatively passed in the county areas, with the advantage to the Imperial Legislature of practical experience locally of the measures proposed.

Centralised administration and subventions from Government have necessarily a tendency to encourage an increased though not always a thoughtful expenditure of public money. If that portion of local taxation which is now collected by the Imperial Government was allocated to the local authorities for collection, such as the game, gun, and dog licenses, house duty, drink licenses, taxes for carriages and armorial bearings, and the subventions were withdrawn, a healthier public spirit would certainly be induced. The subventions by the Imperial Government in aid of local government in England and Wales in 1885-6 amounted to 3,361,858*l*.

Counties of England and Wales, with the number of Urban and Rural Sanitary Authorities and the number of Justices of the Peace, compared with the proposed number of elected Representatives and the total number of Members of the proposed County Councils.

(Practically the number of members of each council would be much less, 80 per cent. of the justices not attending to county business through age, non-residence, being on the commission for more than one county, &c.)

County	Authorities		Justices	5 proposed Representatives of Authorities	Members of County Councils
	Urban	Rural			
England—					
Bedford[1]	3	6	77	45	122
Berks	8	12	178	100	278
Buckingham	7	7	107	70	177
Cambridge (with Ely)	8	8	80	80	160
Chester	4	11	299	75	374
Cornwall	20	13	157	165	322
Cumberland	13	8	180	105	285
Derby	33	9	197	210	407
Devon	33	16	340	245	585
Dorset	11	12	184	115	349
Durham	28	15	215	215	430
Essex	20	15	229	175	404
Gloucester	18	16	260	170	430
Hereford	4	8	220	60	280
Hertford	12	13	208	125	323
Huntingdon	5	3	58	40	98
Kent	39	26	331	325	656
Lancaster, North	11	6	140	85	225
„ North-east	20	5	134	125	259
„ South-east	56	6	260	310	570
„ South-west	41	7	188	240	428
Leicester	11	10	163	105	268
Lincoln	24	14	214	190	404
Middlesex[2]	21	4	401	125	526
Monmouth	17	6	174	115	289
Norfolk	12	19	188	155	343
Northampton	9	12	150	105	255
Northumberland	20	11	126	155	281
Nottingham	13	7	116	100	216
Oxford	9	8	137	85	222
Rutland	0	2	28	10	38
Salop	13	14	235	135	370
Somerset	17	17	307	170	477
Southampton	23	3	237	130	367
Stafford	41	15	312	280	592
Suffolk	11	17	251	140	391
Surrey	16	11	260	135	395
Sussex	22	21	287	215	502
Warwick	15	12	209	135	344
Westmoreland	7	3	102	50	152
Wilts	13	17	214	150	364
Worcester	16	12	234	140	374

[1] When the authority is both urban and rural it has been reckoned as urban alone.

[2] Forty-seven metropolitan urban authorities are not now considered, as no doubt they will be specially legislated for under a London Municipal Reform Bill.

COUNTIES OF ENGLAND AND WALES, &c.—*continued.*

County	Authorities		Justices	5 proposed Representatives of Authorities	Members of County Councils
	Urban	Rural			
England (continued)—					
York, East Riding	9	9	130	90	220
,, North ,,	20	17	249	185	434
,, West[1] ,, (north part)	46	6	144	260	404
,, ,, ,, (south part)	59	12	144	355	499
,, ,, ,, (east part)	37	9	143	230	373
Wales—					
Anglesey	3	2	57	25	82
Brecknock	4	4	125	40	165
Cardigan	4	5	144	45	189
Carmarthen	5	5	119	50	169
Carnarvon	10	4	96	70	166
Denbigh	5	3	126	40	166
Flint	4	3	89	35	124
Glamorgan	16	9	244	125	369
Merioneth	5	4	80	45	125
Montgomery	5	5	87	50	137
Pembroke	4	3	115	35	150
Radnor	2	2	67	20	87

The Imperial Cabinet arrangements would be little affected, the Home Office having at present some control over county police, prisons, reformatories, &c.; the Local Government Board taking poor-law administration, public health, and sanitary supervision; and the Board of Trade having important duties with regard to trade, bankruptcy, railways, and shipping. The Privy Council has already been relieved of a great proportion of its local government duties by the two latter comparatively new departments, and its functions in that respect are now little more than the control (by committees) of the Education Acts, Pharmacy, Medical, Dentists, and Veterinary Surgeons Acts, Destructive Insects and Contagious Diseases (Animals) Acts, and the consideration of charters of incorporation. Under the proposals made the new county authorities would arrange the police magistrates' districts, the appointments to which would probably be made by the Treasury in conjunction with the highest law officers; and the cabinet departments of the Imperial Government would still retain the regulative control of the important local government matters committed to their charge.

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2. *On the Distribution of Wealth in Scotland.* *By* RALPH RICHARDSON, *F.R.S.E.*

The author gave an analysis of Scottish personalty left in 1876, which he estimated at 15,102,119*l.*, and showed how it was distributed among the various counties of Scotland, more than sixty per cent. belonging to the south-western and south-eastern counties as grouped in the census of 1881. He then considered the average estate given up, which was 3,222*l.* per estate for all Scotland; and thereafter the testate and intestate estates, 13,425,916*l.* representing the former, and 1,676,203*l.* the latter. After stating that 12,947,846*l.* had been left by males, and 2,154,273*l.* by females, and that the amount for the county of Edinburgh was 3*l.* 18*s.* per head of the female population, whilst for Lanark it was only 15*s.*, he

[1] In the case of the West Riding the numbers are approximate in the divisions, though the total is correct.

investigated the personalty left by farmers, which was 1,073,348*l.*, or an average of 1,860*l.* per farmer, and concluded by noticing the large estates (100,000*l.* and above) left in 1876.

3. *On the Application of Physics and Biology to Practical Economics.* *By* PATRICK GEDDES.

Having at the last two meetings brought before the Section—(1) An analysis of the biological aspects of political economy, *i.e.*, of the facts of organisation of labour, social progress, &c., viewed in terms of the laws of physiology and evolution, and (2) an outline of the physical aspects of the subject, *i.e.*, of the production and consumption of wealth expressed in terms of the doctrine of energy, the writer now desires (3) to outline the combined application of these departments of theory to the systematisation of practical economics; the current vague general conception of this, in terms of 'progress in wealth and population,' being replaced by that of the development of natural resources towards personal and social maintenance and evolution.

MONDAY, SEPTEMBER 5.

The following Reports and Papers were read:—

1. *Report of the Committee for continuing the inquiries relating to the teaching of Science in Elementary Schools.*—See Reports, p. 163.

2. *Schools of Commerce.*[1] *By* Sir PHILIP MAGNUS.

For some time the opinion has been gaining ground that education must be directed towards commercial pursuits as well as towards those connected with productive industry; that for the maintenance of our trade and commerce fitting instruction must be provided for those who are to be engaged in *distribution* as well as in *production.* The urgency of the need of improved technical instruction has called attention, in the first place, to the importance of satisfying this great want. During the last few years successful efforts have been made to place our technical instruction on a more satisfactory footing. The improvement is seen in the work of our university colleges, in the schemes of the Charity Commissioners for the establishment of secondary schools, in the development of evening technical classes under the City Guilds Institute, and in the opening of a central institution in London for the training of teachers. There are many indications that the claims of commerce will be now considered.

Of the want of more systematic commercial education there is little doubt. Improvements in the means of production will not alleviate commercial depression, unless markets are found for the cheapened products. The valuable consular reports which are now periodically published show unmistakably that we lose trade, not always and solely because we cannot manufacture as well as our competitors, but often and equally for want of knowledge of the places where markets for our goods may be found and of the requirements of the markets it should be our business to satisfy. This knowledge is supplied to merchants abroad by well-educated agents skilled in business habits, conversant with foreign languages, and familiar with the physical, social, political, and commercial circumstances of different parts of the world; and this knowledge, it is contended, is afforded by the system of education adopted in Germany and in other countries, and places men of commerce in these countries at an advantage over those at home. Moreover, the answers to the important circular sent forth by the London

[1] Published in the *Contemporary Review*, December 1887.

Chamber of Commerce have shown that foreign clerks are employed largely by mercantile firms in London, to the exclusion of our own. This is to be deplored, not only because so many of our own young men are thereby displaced, but also because these foreign clerks, when they return to their own country, often utilise, as competitors in trade, their knowledge and experience here acquired.

These facts necessitate (A) an investigation into foreign systems of education with the view of ascertaining what advantages, if any, foreign youths possess over our own as preparing them for mercantile pursuits; (B) a consideration of the extent to which it may be desirable to modify or supplement our own system of education in order to place similar advantages within reach of our own people.

A. (1) *Foreign Schools of Commerce.*—Inquiries into foreign systems of education, made by the author, individually, and as a member of the Commission on Technical Instruction, show that numerous special schools of commerce are found abroad, and that besides these special schools secondary education abroad is better organised as a preparation for commercial pursuits than it is at home. In France, besides the *École des hautes Études commerciales* in Paris, there are eight or nine commercial schools, and several higher elementary schools having a commercial in addition to a technical side. In Germany, the well-known *Real Schulen* afford a first-rate preparation for industrial, including commercial, pursuits; but besides these there are seventeen special schools of commerce, six gymnasiums, and real schools with a commercial side, nine middle schools of commerce, and a large number of evening commercial classes. For the highest commercial education there are special courses at some of the polytechnic schools. Austria-Hungary has nine academies of commerce, including the well-known school at Vienna, eleven middle commercial schools, and forty-two schools intended principally for clerks. Italy, a country in which education is making great strides, is distinguished by its numerous technical institutes, many of which have a special commercial department. It possesses, besides, five high schools of commerce, including the school at Genoa, which has only recently been opened. Belgium, in addition to the excellent High School of Commerce at Antwerp, has a well-organised system of middle schools which give an education especially adapted to commercial purposes. Switzerland has a number of good secondary schools, including the industrial schools, in which the instruction of the children is specialised with a view to commerce. It appears, therefore, that abroad abundant opportunities are afforded of giving a child a special commercial training, and that a large proportion of children receive a good secondary education on modern lines.

(2) *Curriculum of Foreign Schools.*—In the foreign schools of commerce special attention is given to the teaching of modern languages, to which from ten to twenty hours are devoted a week. Geography, a subject of wide import, the full meaning of which the Royal Geographical Society is endeavouring to make Englishmen understand, is well and carefully taught. The mother-tongue, mathematics, elementary science, bookkeeping, political economy, the study of merchandise, office practice, and some other subjects, which vary in different schools, occupy the rest of the pupils' time. In this wide curriculum, perhaps the only subject of uncertain value is the office practice—the *bureau commercial*—which forms an important part of the instruction in the schools of France and Belgium, and is taught to a less extent in the schools of other countries. The system consists, briefly, of carrying on between different classes of a school, as between different countries, commercial transactions; in writing in the appropriate foreign language all letters and necessary documents; in calculating exchanges, and in making up and transmitting bills and accounts, with due regard to different standards of measurement and coinage. Whether this application is carried too far is a debatable question.

B. *British Requirements.*—We have now to consider in what respects our own education needs to be improved or supplemented to afford the necessary preparatory training for a commercial career. This leads us to inquire whether special schools of commerce are necessary, and, if so, what should be the curriculum of such schools. The higher fees paid abroad for instruction in these schools would seem to show that the education provided in these schools is duly appreciated. At the same time, what is most needed in this country is: (1) the establishment of

good higher elementary and middle schools with a technical and commercial side; (2) the reorganisation of our secondary education with the view to the provision of good modern schools, or departments of schools; (3) the provision of facilities for advanced commercial instruction at our local university colleges; and (4) the provision of adequate evening teaching, adapted to the requirements of clerks and of others engaged in mercantile pursuits.

As regards subjects of instruction, the most important consideration is that of foreign languages, which must be taught quite differently from hitherto, *i.e.*, first, for their *use* in reading, writing, and speaking; secondly, for the *discipline* they afford. This applies to the teaching in all grades of schools. Next comes instruction in commercial geography, the teachers of which have yet to be trained. This also applies to the teaching in all grades of schools. Then comes the question of commercial museums, which should be found in all higher elementary and modern secondary schools. Assistance in the furnishing of these museums should be afforded by the Imperial Institute. This institute should do for commercial teaching what the Science Museum, not yet erected, should do for science teaching throughout the country. In the organisation of such commercial museums for schools of various grades there is a great sphere of usefulness for the Imperial Institute. In the higher elementary schools book-keeping should be taught as a branch of commercial arithmetic, and in these and higher schools instruction should be given in the principles of political economy. In our university colleges courses of lectures might be given on various subjects connected with mercantile pursuits. Our evening classes should afford opportunities for practice in speaking and writing foreign languages, and should supply good instruction in commercial arithmetic, book-keeping, shorthand, and commercial geography. If these additions were made to our present means of education, the question of the establishment of special schools of commerce, of courses of application, and of the advantage of introducing office practice, or the *bureau commercial*, into school-work, might be postponed for subsequent consideration.

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3. *Manual Training a Main Feature in National Education.* *By* William Mather, *M.Inst.C.E.*

Our national system of public elementary education having reached its full development for present needs, so far as school accommodation and the effect of compulsory attendance are concerned, it becomes of vital importance to the nation to consider:—

1st. Is the money of the nation being spent to the best advantage?

2nd. Are the children of school age from five to thirteen receiving such instruction and training as shall best fit them for the occupations of what are termed the working classes, and do the results of the present method of teaching enable parents to select occupations in accordance with the natural proclivities and aptitudes of their children? Are the perceptive and constructive faculties awakened and directed, the desire aroused to pursue productive physical work from the love of it, and with a true sense of its dignity and use?

3rd. Is the influence of the teaching in our schools in the formation of character such as to encourage individuality, a sense of responsibility and self-respect, and a desire to pursue knowledge and virtue when the tasks and restraints of school are removed?

It is believed by many who, like the writer, are employers of labour, and who come into close relations with the children of the working classes as they pass from school to work, that the present methods of teaching in our public elementary schools do not satisfy the wants of the nation, or do justice to the children who are compelled to attend the public schools.

That constant progress and improvement have been made in methods of teaching since the Education Act of 1871 was passed all will joyfully admit, but the traditional principle has not changed. Memory, rather than the whole mind, is appealed to; names, dates, facts, grammar, rhetoric, literature, have an unreasonable share of the school time. The natural sciences, recently introduced

into our school courses in the higher grades, take a secondary place in the order of studies; lectures and text-books, more than experimental work and proof by illustration, have to be employed from lack of time; thus memory is again relied upon instead of mental digestion and assimilation.

It has been found that the introduction of objects and pictorial illustrations greatly facilitates the efforts of teachers and aids the comprehension of children, although the faculty of observation alone is exercised. How much greater, then, would be the benefit to teacher and pupil if to observation were added the exercise of the faculty of manual production, and if the conception of a truth or a fact should terminate in the creation of an object with the hands to fully demonstrate its properties and qualities?

Thus manual exercises and training would become the best aid to mental development and culture, when continued systematically in conjunction with class instruction.

It will not be difficult to find ample place and time for manual or creative work together with art work, both being based on drawing—mechanical and free-hand—in all our elementary schools, by reducing the time bestowed on subjects of an abstract character in the present Education Code. The change would be one of gradual growth, depending on the qualifying of teachers.

As our technical schools develop, opportunity will be afforded for teachers to be trained in accordance with the duties they will have to perform in the elementary schools.

It is not desirable to teach trades or handicrafts in schools, but it is imperative to combine *work* with instruction, that children may be better equipped mentally than they are at present for all the trades, employments, and duties of life.

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4. *Technical Education: the Form it should take.*[1]
By EDWARD J. WATHERSTON.

The author, whose argument was completely elucidated by statistics, laid down three propositions:—(1) That, side by side with the ordinary elementary instruction given at present, all children should be instructed in drawing, and, after seven years, in elementary science. (2) That children between ten and thirteen years of age should receive definite practical instruction in handicraft work, if necessary, by the exclusion of some of the more purely literary instruction at present given in our schools. (3) That children, after thirteen years of age, should, by means of scholarships or the payment of fees, have the opportunity of perfecting their earlier instruction in higher elementary schools, or, as they are called abroad, apprenticeship schools. Considerable difference of opinion existed as to the age at which children should receive technical instruction. He thought that the Sixth Standard, as proposed by the Technical Instruction Bill, was too high, because if that proposal had been accepted, only 128,151 children, throughout 19,173 schools, would have been eligible for technical instruction. If any standard was to be prescribed—a prescription which he thought unnecessary—the Fourth—in which, last quarter, 454,752 scholars were presented for examination—would be more appropriate. It seemed to be imperative that some technical handicraft instruction should be given, if necessary, to the exclusion of some of the merely literary teaching. For one clever and lucky youth who rose from the National School to the University a thousand—aye, more—would, and must remain at the bench, the anvil, the loom, the engine, the plough. That being so, after the child had learnt to read, write, and cipher well, he should at once be inducted into at least the rudiments of some branch of technical industry that would enable him to master, far more accurately than now, the handicraft he adopted at a later period. He should become a half-time scholar, spending one-half of his time in the literary department, where instruction in drawing and mathematics should be the main features, and the other half in a workshop-school, to which it might be affiliated. In the workshop-school, which

[1] Published by John Lindsay, 104 High Street, Edinburgh.

a boy might reasonably be expected to enter at the age of ten, the instruction should be of two kinds. First, theoretical teaching, including geometrical drawing, machine drawing and construction, mechanics, and chemistry. Secondly, practical workshop teaching, including the production of simple geometrical forms in metal or wood, such as the cube or prism. Wood joints, dovetailing, and other simple work might be added. While very valuable results would have been achieved if the child's school education terminated at that curriculum, he should propose to offer exhibitions from these schools to higher grade or apprenticeship schools for the most promising of the workshop scholars. The curriculum in these apprenticeship schools would vary according to the social and economical conditions of the district. In an agricultural district the pupils should be taught the principles of agriculture and horticulture. The nature and properties of soils and crops and their rotation would, of course, come in. In a manufacturing district the technical teaching would aim at the inculcation of the scientific principles which underlay the particular processes of production. In a district, for example, such as Kidderminster, the scholars would, besides being taught the processes of weaving, have special instruction in design and the artistic grouping of colours. In this way our great centres of agriculture, of manufacture, and commerce could easily establish central technical schools, dealing especially with the productions of their own districts. Applying these general propositions to present circumstances, the author stated that of the 4,553,751 children on the register of inspected schools, 1,411,999—very nearly one-third—were under seven years of age. With reference to them not much change was needed, except that more time should be given to elementary drawing and to object lessons. Drawing could not be taught at too early an age: the moment a child entered a school he should be taught how to use his pencil. With regard to the children between seven and ten years of age, who numbered 1,606,479, a certain amount of elementary disciplinary handicraft teaching might well be introduced as an integral part of the elementary instruction, with the object of training the hand and eye to work together. The evidence collected by the Royal Commission was clear, that our Continental rivals had demonstrated that most valuable rudimentary handicraft teaching could be given in the elementary and primary schools. In all the new elementary schools in large towns in France instruction in handicraft teaching would find an important place. It was greatly to be hoped that under the improved Act of next session they would see such schools largely prevailing in this country. The tax for education need not be increased. The total school income was nearly seven millions—upwards of 2*l.* per head. The State already contributed 17*s.* per child, and, with a judicious distribution of the income between the two kinds of teaching, the State need not pay more. Into the higher elementary school, or apprenticeship school, boys might be drafted at the age of ten, eleven, twelve, according to proficiency, but he should hope in a few years to find most boys of eleven entering such schools. The schools ought to spring out of the industries of their particular districts, and the courses of instruction should be carefully graded—the first and second year's courses aiming at teaching the scientific basis of the various arts and industries of the neighbourhood, and the third being more distinctly professional in character. Schools of a description similar to that were to be found in towns in France and Belgium. The technical schools of the Society of Christian Brothers were well known; and there were schools of the same kind in Sheffield, Manchester, and Glasgow. It was not too much to hope that all over the country there would not be lacking the funds and the public spirit required to establish these much-needed technical schools, which, by judicious management, could be made self-supporting. He strongly advised that night schools should be taken advantage of for the purpose of promoting technical teaching. He believed it would make them more popular, and he should like to see a National League for the advancement and extension of evening schools. The question of the provision of the teaching power was one not difficult of solution. Every training college should be at once called on to provide skilled handicraft teaching for its students; and for the higher elementary schools the Science and Art Department and the City and Guilds Institute would furnish an abundant supply of teachers. The unqualified success of the Science and Art Department argued that, with the permis-

sion of Parliament, a system of workshop-schools would very quickly spread throughout the country under their energetic management. With fully equipped workshop-schools they would raise up a body of scientific handicraftsmen who would quickly regain our former prestige in the great manufactures in metal, and wood, and textile fabrics. Thus they would be able to defy the keenest competition of our foreign rivals, and to maintain the commercial supremacy of this great Empire.

5. *Manual Training: an Experiment at Keswick.* *By the* Rev. H. D. Rawnsley.

Our country needs not only cleverer artisans with greater wage-earning capacity, but men whose whole capacities, hand and brain and feeling, shall be drawn out, that so happier lives, as well as more useful, may be the result. This should be incentive to the industrial art-teacher.

Lower motives to the work of educating industrial art-workers exist.

(1) A rich class with taste to buy good hand work is bent on securing it for its domestic luxury.

(2) Competition of foreign handcrafts bids us wake to the importance of looking to the training of English hands.

Decentralising agencies needed. Industrial arts, by making people content to stay and work at them in the country towns and villages, will help in this direction.

A feeling encouraged for art and observation of nature will keep alive and preserve the individuality of the workmen in the hard mechanic city rounds of industry.

The best nurse of art and feeling for it, a quiet country-side well loved. Our country-sides feed the town. Let us push forward industrial arts in country places.

After a history of the industrial art experiment at Keswick and a description of a visit to the school on a working night, the author summed up the results of the attempt:—A possible focus for artistic feeling and talent in the community. Surprise of speed in learning the use of the hand. A certain accustoming of the eyes to good strong design, and a deep feeling for good design developed. Discovery that good work is slow work, and that intrinsic merit, not money's worth, is the thing to be striven after.

6. *Home Education in its Bearing on Technical Education.* *By* Miss C. M. Mason.

Twenty years hence it will be no longer necessary to urge so obvious a necessity as that of technical education in the sense of the best conceivable *special* training for a special calling. But, alas! those of us who are already engaged in such training will echo a sigh over the material which comes to hand. You cannot make a silken purse out of such sow's ear. We must 'hark back;' the specialist is produced in his cradle, or earlier, and the technical educator makes ropes of sand until he works with the co-operation of parents. 'The training of children,' says Mr. Herbert Spencer, 'is dreadfully defective, and in great measure it is so because parents are devoid of that knowledge by which this training can alone be rightly guided.' Send a youth, equipped with the habits of the trained intelligence, the habits of the good life, to learn the technicalities of his calling, and the enthusiast sees with leaps of heart all that might be made of him. But such material is beyond hope to most of us. Our effort is to help lame dogs over the stile, since few but lame dogs offer. But the lameness is preventible. Education enfolds infinite possibilities, and perhaps we have yet to see the noble and lovely human being resulting from an even approximately perfect scheme of education worthily carried out. What, practically, is education? Let me offer a definition, by no means exhaustive, but bearing on that view of the subject before us to-day. *Education is the formation of habits.* Pending the development of the will, which arrives at maturity, if ever, only with the maturity of the man, it

appears to me that *habit* is the instrument put into the hands of the educator wherewith to supplement the weak will of the child, and to enable him to make those good and necessary efforts to which human nature is averse. Do a thing a hundred times in succession without lapses, and it becomes as easy to do it as not; do it a thousand times and it becomes your nature, a *habit* which you must do violence to yourself to break through.

It is well established that the tissues, as muscular tissue, form themselves according to the modes of action required of them. Hence the importance of not allowing the child in any posture which should lead to malformation or disease. But what we are less prepared to admit is, that new brain-tissue is supposed to 'grow to' any habit of thought in force during the time of growth—'thought' including every exercise of mind and soul. 'The cerebrum of man grows to the modes of thought in which it is habitually exercised,' and, says Professor Huxley, 'the possibility of all education is based upon the existence of this power which the nervous system possesses of organising conscious actions with more or less unconscious or reflex operations.' What follows? If the very conformation of the child's brain depends in no slight measure upon the habits which his parents permit or encourage, and if the *habits* of the child ensue in the *character* of the man, then this theory of habit becomes the natural basis of a scientific scheme of education. In a successful technical training, especially, a groundwork of carefully considered, carefully laid habits is of fundamental importance. Further, it is in the plastic seasons of infancy and early childhood that such foundation can best be laid; therefore *parents* are the primal and natural educators, and technical or other advanced education can be attended by great success only so far as the intelligent co-operation of parents is secured.

But how are parents to be reached? Is it to be expected that the average parent should make on his own account the enormous educational effort which should enable him to educate his child on rational principles? It *is* to be expected of him, and *he will do it*, provided that the duty be duly and persistently put before him. He may have lost some facility in acquiring new habits, but he has gained in enthusiasm—parental enthusiasm, perhaps, with one exception, the strongest of any. At last, perhaps, the time has come for organised, persistent efforts to bring the principles of a rational, scientific education home to every parent according to his degree—on simpler lines for the young artisan and his wife; on more scientific for the more highly educated. Associations or other efforts for the further education of parents, made upon principles of self-help, of give and take for mutual improvement, should meet with a ready response; and thus the experience of the most thoughtful in any community would be utilised for the benefit of all.

SUB-SECTION F.

1. *The Classification of the Exports of Cotton Piece Goods in Board of Trade Returns. By* FRANK HARDCASTLE, *M.P.*

This paper is the outcome of an effort made last year by the Manchester Chamber of Commerce and the United Bleachers' Association to obtain a new and more discriminating classification of the above exports.

Hitherto cotton piece goods have been classified as (1) 'unbleached or bleached,' (2) 'printed or dyed,' (3) 'mixed goods, cotton predominating.' Last autumn, however, the Customs and Board of Trade consented to try experimentally for four months at the beginning of this year a new classification—viz., 'unbleached,' 'bleached,' 'printed,' 'dyed or manufactured of dyed yarns,' 'mixed goods, cotton predominating,' and a copy of these experimental returns is given along with the paper.

When sending these returns in manuscript to the Manchester Chamber Mr. Seldon, the head of the Statistical Department of the Customs, expressed grave

doubts as to their accuracy, as he had not received the support and assistance from the exporters that he expected, and the agents at the ports had in many cases to make guesses as to the nature of the exports.

The object of this paper is to show that, notwithstanding this, the returns show a considerable amount of substantial accuracy, and are most interesting and useful, particularly to the bleaching and calico-printing industries.

As evidence of this the returns from the Indian Customs are taken of the total imports into India of cotton piece goods from all countries for 3½ years—viz., from April 1, 1883, to September 30, 1886, which are compared with the Customs Returns in the following statement:—

	India Customs (3½ Years)	United Kingdom Customs Returns (4 Months)
	per cent.	per cent.
Unbleached	63½	67
Bleached	17½	18
Printed and dyed . .	19	15

The paper goes on to examine the returns from the Chinese Imperial Customs, which to a certain extent discriminate between unbleached and bleached goods.

The values of the different classes of exports to India as shown in the United Kingdom Customs Returns are somewhat corroborative of the substantial accuracy of the returns: unbleached, 2·1*d.*; bleached, 2·5*d.*; printed, 2·95*d.*; dyed, 3·67*d.* The differences here shown in the values of the different classes pretty closely correspond with the average cost of each different operation of bleaching, printing, and dyeing.

The paper goes on to point out some features of interest in the returns, and claims that their value is sufficient to justify their being continued, and calls on exporters to facilitate the work of the agents at the ports by furnishing the necessary details of their exports.

2. *The Statistics of our Foreign Trade, and what they tell us. By* A. E. BATEMAN, *F.S.S.*

The author submits this paper on the chief features of our trade returns in view of the many misconceptions regarding them and the interest attaching thereto in these times of controversies about free trade and currency questions.

He describes the various official publications, monthly accounts, annual statement, &c., and discusses the methods adopted in their compilation in regard to classification of articles, valuation, registration of real origin, and destination of imports and exports compared with the systems in use abroad and in connection with recent discussions at the Congress of the International Statistical Institute. He shows the difficulty of classifying articles into manufactures, raw materials, food, &c., and gives the various foreign classifications; and he points out that our system of declared values gives an immediate record of changes of price of imports and exports which foreign systems of official values revised only yearly or biennially fail to do; but the intelligent and benevolent co-operation of our manufacturers and merchants is essential to getting current returns. After showing the importance of settling these bases of trade statistics he invites views and suggestions for any improvement in the returns from the many competent authorities who are likely to be present.

He concludes by some comments on the chief points of interest in the monthly accounts, showing that if read intelligently they present a very graphic picture of the economical changes which are daily, and almost hourly, taking place.

3. *Report of the Committee on the Regulation of Wages by means of Lists in the Cotton Industry.*—See Reports, p. 303.

4. *Expenditure of Wages.* *By* D. CHADWICK.

5. *History of the Cotton Trade.* *By* W. ANDREWS.

TUESDAY, SEPTEMBER 6.

The following Papers were read:—

1. *Gold and Silver; their Geological Distribution and their probable Future Production.* *By* W. TOPLEY, *F.G.S.*—See Reports, p. 510.

2. *An Attempt to bring the Issue between those who are called 'Mono-metallists' and those who are called 'Bi-metallists' into such Terms that an Intelligent Public Opinion may be formed thereon.* *By* EDWARD ATKINSON.

Bi-metallism exists *de facto* everywhere.

Silver coin has not been demonetised anywhere.

Modern commerce cannot be conducted without the use of both metals in the form of coin.

The real issue has been obscured by a misuse of terms.

It is simply this, Shall coin made only of gold be a full legal tender from a debtor to a creditor, or shall coin made of either metal at a certain ratio of weight be such full tender at the option of the debtor?

Is not the enactment of any statute of legal tender a question of convenience or economy rather than one of necessity?

Can coins made of silver and of gold at the ratio of fifteen and a half parts of the one to one part of the other, or at any other stipulated proportion, be made universally convertible or interchangeable by an *international act of legal tender*?

Would such an act do away with the existing variations in the rate of exchange, and bring all coins of gold or silver to par, due regard being given to the cost of moving coin or bullion, all mints being open to free coinage?

What would be the probable effect of such a statute on the future production of gold and silver bullion?

In the investigation of this question I have been impressed by the want of precision in the case. The issue is not fairly joined and is very indefinite.

3. *On the Solution of the Anglo-Indian Monetary Problem.* *By* Professor L. WALRAS.

The problem of the organisation of the monetary relations of England and India upon a rational footing would be determined in the following way, according to the system of *gold standard money with a regulating silver token currency* [*monnaie d'or avec billon d'argent régulateur.*]

Neglecting, for the sake of simplicity, the fractional currency [*la monnaie divisionnaire*],

Let Q_g be the quantity of gold money existing in England;

Q_s the quantity of silver money existing in India;

w the market ratio [*rapport actuel de la valeur*] between gold and silver.

Then if, after having first of all suspended the free mintage of silver in India, we were, on the one hand, to take a quantity x of silver in India to carry it to England and make it discharge the function of a regulating token currency, alongside the gold standard currency, on the basis of the legal ratio w' of the value of gold to the value of silver; and if, on the other hand, we were to take a quantity y of gold in England to carry it to India, and make it discharge the function of

standard money, alongside the silver, now transformed into a regulating token currency, on the basis of the legal ratio w'' of the value of gold to the value of silver: it would be necessary, in order that the value of money should be the same in England and India, that the new quantities of standard money, and of token money valued in gold, should be in the same ratio as the former quantities valued in the same way; that is to say, we must have

$$Q_g - y + \frac{x}{w'} : \frac{Q_s - x + yw''}{w''} :: Q_g : \frac{Q_s}{w};$$

from which it follows that

$$x = \frac{(w - w'')Q_g Q_s + w''(wQ_g + Q_s)y}{wQ_g + \frac{w''}{w'}Q_s}.$$

It will be observed that w', w'', x, and y are not absolutely determined, and that three of these quantities may be arbitrarily assumed. Let us suppose, then, merely for the sake of giving definiteness to our ideas, that the quantity of gold standard money at present in England, Q_g, is 750,000 kgr., and that we only wish to take for transport to India a portion y, representing one-third of this total quantity, say 250,000 kgr.; and that the quantity of silver standard money at present in India, Q_s, is 25,000,000 kgr. Let us suppose that the actual market ratio of gold to silver is 1 to 20. And lastly, let us suppose that, in order not to disturb Indian usage, it should be decided to constitute the regulating token currency in India of the present rupee, at the rate of 10 rupees to the 1*l.*, which would give w'' = about 14·60; and that similarly, for some reason or other, it should be decided to constitute the regulating token currency in England of four shilling pieces, of exactly the same weight, fineness, and remedy as the Latin Union crown of 5 francs, which would give w' = about 15·36. In the conditions thus assumed, the quantity x of silver to be taken up in India for transport to England would be about 6,378,500 kgr.

This quantity must be decomposed into two portions: one of 2,728,500 kgr., to be transported without equivalent, and one of 3,650,000 kgr., to be transported in exchange for 250,000 kgr. of gold. The first operation might be effected by means of a loan raised by the State in India, the produce of which should be employed in the purchase of Consols in England. The second operation might be effected by means of an issue of notes by the Bank of England, by which gold might be obtained to exchange against silver in India. These two operations would result in a considerable loss, in the conditions we have assumed, on account of the superiority of the ratio $w' = 15·36$ over that of $w'' = 14·60$, since the State and the Bank would give 1 of gold (or its equivalent) for 14·60 of silver in India, and 15·36 of silver against 1 of gold (or its equivalent) in England. This loss might be covered in the following way.

A fall in the value of gold would certainly bring about a transformation into gold merchandise of part of the present amount of gold money, and the export to foreign countries of another part. To supply the deficiency there would be occasion for making a supplementary addition of regulating token currency to the two quantities $x = 6{,}378{,}500$ kgr., and $Q_s - x = 18{,}621{,}500$ kgr., which are assigned by our formula to England and India respectively. That is to say, the quantity of silver to be taken up in India for transport to England would have to be reduced; and in order to meet this reduction, as well as in order to defray the deficit, we should have occasion in England to transform silver merchandise into silver regulating token currency. Let us suppose the deficit to be provided against were 75,000 kgr. of gold, of which 50,000 kgr. were for England and 25,000 kgr. for India. We should be able to reduce the quantity of silver to be taken up in India to 6,013,500 kgr., or, in other words, to raise the quantity of silver to be left in India to 18,986,500 kgr.; and to coin in England 1,133,000 kgr. of regulating token currency; and this mintage would give a profit sufficiently large to cover the loss which would arise in the other part of the operation.

In this way the value of the rupee would be raised to two shillings. It is

evident that the difficulties of the operation would be diminished if the value were only raised to a lower point. For instance, if it were enacted that 12 rupees should go to the 1*l.*, which would only bring the value of the rupee to one shilling and eightpence, thus giving us $w''=17\cdot50$ about, x would then be equal to 5,102,568 kgr., of which 727,568 kgr. only would have to be transported without equivalent, and 4,375,000 kgr. would have to be transported in exchange for 250,000 kgr. of gold. And the two operations would give a profit, to which there would be added the profit to be realised as the result of the transformation of silver merchandise into regulating token currency.

If it were not thought possible or proper to make any movement of floating capital, in the form of money, from India to England, we should have to lay down, as a new condition, that the quantity of silver imported from India to England should be exactly balanced by the quantity of gold imported from England to India; that is to say, we should have to assume

$$x=yw'',$$

an equation which, taken with the preceding one, gives us finally

$$y=\frac{w'(w-w'')}{w''(w''-w')}Q_g,$$

in which two quantities only remain to be arbitrarily determined. It follows immediately that, in order that y may not be too large a fraction of Q_g, w' must be as small as possible, and w'' as large as possible.

WEDNESDAY, SEPTEMBER 7.

The following Papers were read:—

1. *Food as an Aid to Elementary Education.*[1] *By* GEORGE HERBERT SARGANT.

The plan of providing needy children with food at school dates at least as far back as 1846. Again, about 1859–60, a period of depressed trade like the present, produced cheap dinners for school children, and schemes for providing cheap meals for the working classes. Records have been preserved of the early successes of such ventures, but none of their subsequent failure. Similar schemes are now succeeding, and it will be interesting to watch whether they will be more permanent.

Attention was directed by Mr. Mundella in the House of Commons on July 26, 1883, to Sir Henry Peek's penny dinners at Rousdon. Dr. J. A. Campbell afterwards gave particulars as to similar work at Farnell, N.B. And the experiment was successfully tried on a large scale by the Rev. Moore Ede, at Gateshead.

At Birmingham in the winter of 1884–85, penny dinners were found to be beyond the means of the really poor children. The price has therefore been lowered to a halfpenny, and even to a farthing, but at the same time it has been necessary to give large numbers of the meals free. During last winter (1886–87), four-fifths of the meals were free.

The children to whom they were given get little or no food at home; they are insufficiently clothed, usually in rags. Their home life is miserable, and though in most cases the influences are not altogether for evil, in many they are hopelessly bad. Reduced by privation, they cannot resist disease; they cannot eat, many are quite unfit for school work.

The reports as to the results of the children's dinners have been so unsatisfactory that I, last winter, tried to make some accurate observations. Children, selected for their great need of food, were fed regularly for some time and their condition before and after carefully recorded. The results thus observed, after being compared with other information, have been divided under three heads:—

PHYSICAL.—Marked improvement in appearance and spirits, and in power to

[1] The paper appears *in extenso* in the *Fortnightly Review* for September 1887.

resist disease, and to take food: boys who were $1\frac{2}{3}$ years behindhand in height and weight seem to have grown faster than the normal rate.

EDUCATIONAL.—Chiefly improved attendance, amounting to at least six per cent. at poor schools, and making winter attendance equal to summer. As to power to work, evidence is conflicting.

MORAL.—The beneficial effect on ill-disposed children is very rapid. Moreover, there is less casual begging and pilfering by children who might pick up their own living if not compelled to attend school.

The cost of dinners sufficient to meet the needs of average poor-school children is, at the kitchens under my control, less than a halfpenny each, including all expenses except management. If the scheme stood quite alone the cost might be three farthings per meal, or 6*s.* 5*d.* per 100. At 225 meals a year the cost of feeding each child would therefore be 14*s.* There are rather more than eight millions of children between 5 and 15 in the United Kingdom. Of these about 4 per cent., or 330,000, would appear to need free meals, more in winter, less in summer. At 14*s.* a year each the cost would be 230,000*l.* A quarter of a million a year would feed all underfed children.

Compulsory education precludes these children from picking up or earning their own living, and a scheme for compensating this loss and for meeting the additional strain of school work seems a natural complement of our Education Acts.

It would be far better that this should be done through private charity, but it would seem desirable to enquire whether private charity is sufficient, and, if not, whether other means might not be taken.

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2. *Phthisis Centres in Manchester and Salford.* *By* ARTHUR RANSOME.

Tubercular disease has been shown to be closely associated with the presence of a micro-organism, derived from the atmosphere, but the spread of the disease in a community is conditioned by many circumstances, the chief of which are:

a. Hereditary predisposition of the inhabitants.
b. The frequency of other respiratory affections.
c. Bad ventilation of workshops, living-rooms, &c.
d. Damp subsoils.

In Manchester and Salford all these circumstances are to be found in certain districts, but more distinct in some parts than in others. Statistics of the prevalence of phthisis in a certain district (No. 1) of Ancoats, Manchester, and other districts of Greengate and Regent Road, Salford, were supplied to the author by the health authorities of the two boroughs. Descriptions of these districts are given, and the distribution of phthisis is shown to be determined by the nature of the dwellings and the subsoil, and by the nature of the ventilation of the streets in these districts.

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3. *On some important Statistics relating to the Silk Industry.* *By* THOMAS WARDLE.

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4. *On Bimetallism.* *By* J. NICHOLSON.

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5. *On the Position of Economics in Holland.* *By* Professor GREVEN.

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6. *Socialism.* *By* Professor W. GRAHAM.

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7. *On the Increase of Wealth and Population in Lancashire.* *By* WILLIAM E. A. AXON.

The growth of the wealth and population of Lancashire within the last century and a half has been exceedingly rapid. When the British Association visited

Manchester in 1842 some particulars as to the increase of wealth in the county were submitted by the late Mr. Henry Ashworth; and as the progress made since that date has been very remarkable, it may be useful to examine the subject once more from a statistical point of view.

The name of the county of Lancashire does not occur in Domesday Book, but the 188 manors in the district now known by that name are valued at 120*l.*, a sum which Baines, in his 'History of Lancashire,' estimates as equivalent to 13,200*l.*

When the Great Council or Parliament of Westminster, 1352, was held for the purpose of 'settling the staple' or manufactures of the kingdom, the county sent only one representative. The list of decayed towns of Lancashire in 1544 includes Lancaster, Preston, Lyrepool, and Wigan. In the military muster of 1553 Lancashire was called upon for 2,000 men, and in 1559 there were 1,919 'harnessed men' and 2,073 without armour. In 1574 it furnished 6,000 able men, 3,600 armed men, 600 pioneers and artificers, 12 demi-lances, and 90 light horse—standing amongst the most important of the counties in a military sense.

In the same year the gross produce of the tenth and fifteenth taxes was recorded as 376*l.* 11*s.* 11½*d.* The figures for the hundreds were: Leyland, 36*l.* 10*s.* 4*d.*; Blackburn, 48*l.* 8*s.* 6*d.*; Salford, 48*l.* 7*s.* 4*d.*; West Derby, 125*l.* 8*s.* 7*d.*; Amounderness, 66*l.* 17*s.*; Lonsdale, 50*l.* 18*s.* 2*d.* The levy for ship-money in 1636 shows the estimate as to the relative wealth of various places. The contribution of Lancashire was one ship of 400 tons, 160 men, and 1,000*l.* Preston contributed 40*l.*; Lancaster, 30*l.*; Liverpool, 25*l.*; Wigan, 50*l.*; Clitheroe, 7*l.* 10*s.*; Newton, 7*l.* 10*s.* Yorkshire contributed two ships of 600 tons and 12,000*l.* Hull was assessed at 140*l.*; Leeds at 200*l.*; Bristol at one ship of 100 tons, 40 men, and 1,000*l.* London contributed seven ships, 4,000 tons, 1,560 men, and six months' pay.

Mr. Ashworth calculated the value of Lancashire from the land tax in 1692, and compared it with that of the rateable value in 1841. This is the starting-point of the following calculations. The increase of both population and of rateable value has been due to the immense development, in the first instance, of the cotton trade, and to the impetus given by it to other forms of industry. The increase of population in Lancashire may be thus stated:—1801, 672,731; 1811, 828,309; 1821, 1,052,859; 1831, 1,335,800; 1841, 1,667,054; 1851, 2,031,236; 1861, 2,428,744; 1871, 2,819,495; 1881, 3,454,441. The rateable value of the six hundreds into which the county is divided may now be stated. The figures for 1692 are those calculated by Mr. Ashworth, and the later dates are the official estimates for the county basis or standard of rating:—

Rateable Value of the County of Lancaster.

The first column calculated from the land-tax returns; the remainder from the basis or standard for county rates.

Hundreds	1692	1841	1853	1866	1872	1877	1884
	£	£	£	£	£	£	£
Lonsdale .	8,500	291,963	298,275	423,665	514,402	767,630	1,010,772
Amounderness	10,288	364,994	414,691	525,239	592,544	718,018	896,956
Leyland . .	5,774	199,884	199,038	950,663	1,159,472	1,432,206	1,738,740
Blackburn .	11,131	498,286	574,607	248,795	282,236	321,114	370,946
Salford . .	25,907	2,703,291	3,051,347	4,082,799	5,269,222	6,848,754	7,791,862
West Derby .	35,642	2,124,925	2,375,115	3,798,806	4,734,124	5,539,168	6,789,222
	95,242	6,183,343	6,913,073	10,029,967	12,552,000	15,626,890	18,598,498

If we take the townships forming and adjoining the city of Manchester and the borough of Salford, the increase is shown to be very marked. It is notable that the increase of wealth has been progressive, notwithstanding the complaints of trade depression.

Name of Place	Value in 1692			Value in 1841	Value in 1866	Value in 1884
	£	s.	d.	£	£	£
Chorlton-on-Medlock .	256	4	2	137,651	162,952	266,848
Hulme	152	10	5	75,733	180,073	252,034
Ardwick	175	0	0	46,471	69,171	128,928
Salford	809	19	7	162,847	189,587	382,904
Cheetham . . .	215	18	4	38,933	75,470	137,920
Manchester . . .	4,025	0	0	721,743	882,998	1,579,552
Broughton . . .	230	6	8	33,956	70,551	158,896
Pendleton . . .	363	12	11	48,150	84,497	192,420
Crumpsall . . .	95	6	3	13,237	19,895	40,018
Rusholme . . .	146	13	4	15,281	33,906	63,110
Moss Side . . .	61	9	2	4,958	21,691	102,744
	6,531	0	10	1,298,960	1,780,791	3,305,374

These figures measure the industrial progress of Lancashire. Whilst each hundred has had its share of prosperity, the greatest increase of wealth has been in the Salford hundred, which comprises the Manchester district, and West Derby, which includes Liverpool. The average value per acre was, in 1692, 1*s.* $6\frac{11}{12}$*d.*; in 1841, 5*l.* 2*s.* $5\frac{5}{12}$*d.*; and in 1884, 15*l.* 8*s.* $1\frac{5}{6}$*d.* If we compare the rateable value with the population, the proportion per head in 1841 was 3*l.* 14*s.* $2\frac{1}{5}$*d.*, and in 1884, 5*l.* 7*s.* $8\frac{1}{7}$*d.* In less than fifty years the material wealth of the county of Lancaster has trebled.

Section G.—MECHANICAL SCIENCE.

President of the Section—Professor Osborne Reynolds, M.A., LL.D., F.R.S., M.Inst.C.E.

THURSDAY, SEPTEMBER 1.

The President delivered the following Address:—

At a meeting of the British Association in Manchester the subjects of interest to the members of this Section are sure to be numerous, and the attendance of those members whose opinions on the various subjects presented the Section will like to hear is sure to be such that every moment of the time at the disposal of the Section will be well occupied. It is also particularly undesirable to prolong the sittings, and so reduce the opportunities of visiting the exhibition and numerous works which abound with things which cannot fail to be of intense interest to members of this Section.

For these reasons I feel extremely unwilling to occupy the time of the Section with more than the briefest remarks by way of an address. Indeed, were it not that when in this chair in 1872 Sir Frederick Bramwell laid down the rule that for the President to break the custom of an address would be to show disrespect to the Section, I should have felt justified in consulting my inclination and proceeding at once with the regular work which lies before us.

It is now twenty-six years since the last meeting of this Section was held in Manchester, and it certainly seems fitting that in an address on this occasion something should be said as to the achievements in mechanical science accomplished in the interval. I wish sincerely that the task had fallen to some of you gentlemen whose far greater experience and power of expression would have enabled you to do justice to the subject. But under the circumstances I can only ask you to take it as a mark of my extreme respect for the Section, and proof of the appreciation in which I hold the honour conferred upon me in placing me in this chair, that I venture as a matter of duty to make a few remarks of the inadequacy of which I am only too conscious.

It is always difficult to arrive at a just appreciation of the relative importance of the events of our own time; and in any endeavour to review or take stock of the mechanical advance of the last quarter of a century, during which time things mechanical have divided the attention of the civilised world with matters political, it seems very necessary to remember that as the mechanical age gets older its relative activity is not to be gauged by the relative number and importance of such epoch-marking mechanical departures as compared with those which have distinguished past periods.

If you recall—and again, to quote Sir Frederick Bramwell, the only purpose of an address is to force you to recall what you already know—in 1861 not only had we railways, ocean steamships, including the 'Great Eastern,' still the giant of the tribe, a complete system of machinery for cotton and textile fabrics, besides the steam hammer, Armstrong's accumulator, and types of all machine tools, but also one attempt had been made to lay an Atlantic cable; the Suez Canal was in course of construction; if not perfected, the Bessemer process was in use; as were

steam ploughs, steam thrashing machines, reaping machines, and other agricultural machinery; we had also monster ironclads and rifled ordnance.

As new departures since 1861 which have already established themselves we have the telephone, the incandescent electric light, the dynamo, and the secondary battery, the gas engine and sewing machine, not to mention the bicycle. We have also the tin can and freezing machine and roller mills, as well as the machine gun and Whitehead torpedo.

One of these departures, the telephone, both from its usefulness and from the scientific interests which surround it, as affording, like the telescope, a means of directly increasing the power and range of one of our senses, must for ever remain recognised as a step in mechanical science, for the introduction of which this period will be distinguished.

The sewing machine, too, though little calculated to attract notice, in its influence on the welfare and appearance of all grades of society yields in importance to few, if any, previous mechanical steps. While the process of preserving food by means of the tin can and its more striking contemporary, the freezing machine, direct results of the discoveries of Pasteur, have already opened up the food-producing resources of the whole world for the supply of the few chosen spots, and in doing so created a most welcome demand for further advance in the application of steam.

Great things have been and still are hoped from the electric departures which have interested us so much during the last few years; also of the gas engine, which has most usefully occupied ground for which the steam engine is not well adapted; and as to the importance of machine guns and torpedoes many will think the less the better.

However high or low an estimate we may form of the probable future importance of some of these inventions, and however much disappointment we may feel at the non-success which has attended some of the boldest and apparently most promising departures, such as the Crampton process for substituting a blast of coal-dust for the ordinary furnace, or Sir Henry Bessemer's endeavours to prevent distressing motion at sea, there is still no ground for discouragement.

For whether or not this period be henceforth remarkable for what, to borrow language from Section D, may be called the origination of new mechanical species, is a small matter compared with the fact that it has undoubtedly been remarkable for unprecedented achievements in the development of higher states of organisation in those mechanical species which were already in existence.

There has never been a time in which mechanical revolutions have followed one another with such rapidity. In all the main departments of practical mechanics progress has been so rapid that appliances have been superseded long before reaching the term of their natural existence. There are some steamboats like the steel mail-boats between Dover and Calais still on the same service as in 1861, but very few, and only such as were then much in advance of their time. The Atlantic fleet of Royal Mail steamers has twice undergone complete revolution. Not only have the paddle-boats which constituted the Cunard line in 1861, and which included the 'Scotia,' then new, entirely disappeared off the line, but the iron screw steamers which displaced them have given place to the steel boats with compound engines—'Servia,' 'Aurania,' 'Etruria,' and 'Umbria.'

In railway appliances the iron road has given place to that of steel, iron tires and locomotives to steel, the block system has become general, as have continuous brakes; while the carriages in which members have spent four and a quarter hours on their way from London to this meeting, although mostly still of the English plan, are very different in size and ease from those in which five and a half hours were spent in 1861.

In the works and mills the change is not less complete. It is, indeed, the change here that has not only rendered possible, but forced on the revolution in our means of communication. The great step in the production of steel was already taken in 1861, and great results were then anticipated; there were, however, doubts and difficulties, and it was not for some years that sufficient mastery was obtained over the detail of the manufacture and use of the new material to bring

about the general revolution which has therefore only reached its height during the last few years, if, indeed, it is yet reached—certainly it is yet far from complete.

To turn for one moment to the last year. Since the last meeting of this Section in Birmingham, the second Tay Bridge has been completed, over two miles long, having occupied only five years in construction.

The Severn Tunnel, one of the most difficult pieces of engineering ever attempted, has been completed and opened for passenger traffic.

The Forth Bridge, that structure the very thought of which causes those who have seen the place to hold their breaths, and of which the relative size may be best realised from the fact that, held out in arms an eighth part of a mile long, at a height of 200 feet above the sea, as a mother might hold out an infant, are structures no less than the single spans of the Britannia Bridge, 400 feet long. This gigantic structure, the progress of which Section G has watched since the meeting at Southampton, has now attained its full height of 360 feet, although otherwise not by any means fully formed.

Nor, as you well know, is it by the completion and progress only of great undertakings that this year is marked in the annals of engineering. It will be memorable, particularly in this district, as the year of the commencement of the Manchester Ship Canal. This undertaking, for which there is no precedent in this country, has excited so much interest that it cannot be otherwise than a matter of congratulation that a paper descriptive of this work is to be read before this meeting by the engineer, Mr. Leader Williams.

The completion of the Tay Bridge, the Severn Tunnel, the progress of the Forth Bridge, and the commencement of the Manchester Ship Canal in one year and in one country is sufficient assurance that, as yet, there is no lack of enterprise or sign of falling-off in heroic undertakings; nor are these by any means the only signs of great mechanical activity, notwithstanding the continual complaints of commercial depression.

In one direction, in particular, after many years of progress, so slow as to be something like stagnation, there has been a decided advance. The steam engine is such a familiar institution, and has been for so long looked upon as the prime mover of our entire mechanical system, that anything which affects its welfare excites a deeper interest than would a mere mechanical advance. It was therefore with anything but a feeling of pure exultation that we heard and felt the force of predictions a very few years ago that the days of the supremacy of the steam engine were numbered, that it would soon be a thing of the past, only to be found in the museum, a relic like Newcomen's engine and the stone implements by which our children would gauge the depths of mechanical barbarism of the age from which they had emerged. If sentiment be allowed in relation to anything mechanical, it must be with a sense of relief that it is now perceived how, so far from succumbing in the competition with what threatened to be formidable rivals, the only effect has been to bring about an important step in that internal development of the steam engine, which has been long looked for, but the accomplishment of which had for so long baffled the utmost efforts to bring it to a practical issue that it was almost despaired of—at least until it should be brought about by that circumstance which we all dread, the scarcity of coal.

The uppermost step of this advance yet reached is represented by the triple and quadruple expansion engines. These engines, of which the first seem to have been the triple engines of the 'Propontis' in 1874, designed by Mr. Kirk, the next those of the steam yacht 'Isa,' by Messrs. Douglas and Grant in 1878, and the third those of the 'Aberdeen,' again by Mr. Kirk, in 1881, rapidly sprang into favour for cargo steamers, in which they have already proved of such advantage as to more than threaten the necessity of another revolution in steamships almost before the last is complete. Each week brings the announcement of some new accomplishment in the use of higher ratios of expansion and higher pressures of steam, so that while 60 or 70 lbs. was the maximum three years ago, we now hear of 130, 150, and 175 lbs.; and it is impossible to say to what they have not been carried at the present moment, and with commercial success.

There can be no doubt but that this latest step, as well as those of the surface

condenser, high-pressure boilers, and compound engines which led up to it have been the immediate results of the premium on economy of coal offered by the opening up of the long steam routes, first through the Suez Canal and recently round the Cape. But these steps must none the less be considered as the results of the unprecedented attention and labour, theoretical and practical, which has been devoted to this object during the last fifty years. They have been a result of the theoretical work of Carnot and Regnault, crowned by the great discoveries of Joule and Meyer, and the subsequent work of Rankine, Thomson, Clausens, and Hern, besides others, which about the commencement of the period I am speaking of accomplished that complete exposition of the principles underlying the internal economy of all heat engines which have since furnished incitation and guidance to practical efforts. And not less have they been a result of the many practical attempts which have in the meantime been made to introduce similar and equally effective developments in the steam engine without waiting till they were called forth by circumstances; as notable amongst which I may instance the labours and successes of Mr. Perkins, who has experimentally developed the organisation of the steam engine beyond any point it has commercially reached. Each and all of these efforts has undoubtedly taken part in that readiness to take the forward step, as soon as circumstances were favourable, which is as necessary to development as are the favourable circumstances themselves. The fact that a great advance has been made in the use of higher-class steam engines, while it is the most gratifying circumstance one could have to record, affords the greatest encouragement to all those numerous workers for mechanical advance whose work is good, yet who do not see its immediate effect. It also emphasises the lesson that the most perfect machine is that which is most perfectly adapted to the circumstances under which it has to work; and amongst these circumstances is efficient attendance, which involves sufficient knowledge of its requirements and familiarity with its detail on the part of those who have it in charge; and while in a process of gradual development this education is insured, in the case of a sudden step it is generally wanting.

How far the present advance towards the limits to economy which are theoretically evident may extend in the immediate future it would be dangerous to predict. The present rate is immense, and not by any means confined to the marine engine, although I am not aware of any other class of engine in which triple expansion has yet been adopted as a system. The recent compound pumping engines have attained to very high organisation; and even in those classes of engines where economy of coal is more a matter of morality than of proved commercial importance, as mill engines and locomotives, great activity is evident in adapting and substituting compound engines, so as to allow of the use of greater pressures and higher degrees of expansion. The slow breathing compound locomotive of Mr. Webb has drawn many members of this Association on their way to this meeting. Nor is the portable engine behind, as has been shown by the recent trials of the Royal Agricultural Society at York. The result of these trials cannot but offer the greatest encouragement to engine-makers of all kinds in their attempt at higher organisation. It is indeed difficult to say which has been the most gratifying—the high state of economy which these trials have shown to be realised, or the reinstitution of the trials themselves after a lapse of twenty years, during which interval their non-continuance has called forth but one expression—that of regret.

These almost sudden steps towards the realisation of efforts now extending over a century, to bring higher developments of the steam engine into practical use, have not passed without notice. The interest and excitement amongst those more directly acquainted and concerned with the steam engine and the use of steam are probably such as have not existed since the very early days of the railway. It is not therefore as something likely to be new to the members of this Section that I have dwelt upon it. Remembering that there was another subject other than actual mechanical achievements on which I was, as it were, in duty bound to say something, it seemed hopeless for me to attempt to touch on all the many advances towards a higher degree of organisation in mechanics which constitute the mechanical feature of our era. I therefore have chosen this decided movement of the prime mover as the most significant and most gratifying, besides being of a kind the full

importance of which is not so likely to be generally apprehended until pointed out as the importance of advances such as the electrical and metallurgical, involving some new departure or novel application.

That the character and rate of recent mechanical advance are both exactly such as would be expected to follow, as the result of a deeper and broader knowledge of scientific methods and the principles involved, seems to be the very best proof of advance in that other side of mechanical science in which this Section takes interest, or, more correctly, for which it exists—the increase and spread of mechanical knowledge.

It is as impossible as it is unnecessary for me to comment on the *furore* to which the movement first for popular scientific and now for technical instruction has reached—bringing into existence, by means of South Kensington, a complete system of sensibly free elementary scientific education over the country; then the City and Guilds Technical Schools, with a general system of examination; and culminating in a Parliamentary Commission on Technical Education, with the prospect of seeing its labours result in an Act of Parliament providing for absolutely free technical instruction.

Elementary education, whatever may be its subjects, must of necessity depend for its permanent existence on some source of higher knowledge in those subjects. Without raising such questions as whether there exist at present means of training efficient teachers in all the branches for which technical education is promised, or whether such means will be forthcoming as a result of the demand for teachers, I would recall to your attention the recent progress made towards a higher training in that branch of science which most directly relates to mechanical progress, and which, according to no less an authority than the late Professor Rankine, received its first impulse from the institution of Section G.

So long ago as 1855 Rankine, in his characteristically concise address, dwelt upon the good work which this Section was doing in making it known that the application of the laws and principles of abstract mechanics to the purposes of practical mechanics constitutes a science of itself; a science the knowledge of which is essential before a knowledge of mathematics and abstract science can be of use to the practical engineer or mechanic; and for this science he then and there claimed the name Applied Mechanics. As a proof of the influence of Section G in making known the usefulness of this science he instanced the apparent increase in the desire to profit by the lectures of the late Professor Lewis Gordon, which had taken place since the Section was instituted.

Professor Gordon, who held the chair of mechanics in Glasgow University, was the first in this country to collect and embody in his lectures, and subsequently in a text-book, the important though scattered results of individual efforts to found the laws of practical mechanics on exact science. And at the time Rankine was speaking, this chair, to which Rankine himself was called the same year, was the only chair in this country from which such lectures were given.

Since that time the appreciation of that science has steadily increased; other colleges took up the subject mostly as forming part of courses entitled engineering or naval science. Amongst these was Owens College, in which, not till after the last meeting in Manchester of this Association, the leading engineers founded and endowed, which is more important, the chair which it has been my fortune to occupy for nineteen years.

During the earlier part of this time both teachers and students were labouring under the disadvantage arising from the novelty of the subject—the former having to make an almost arbitrary selection of what they would teach, and the latter not knowing exactly what it was they were going to learn. Gradually, however, by the help of experience from the somewhat earlier French schools and with the admirable works of Rankine as a foundation, the lectures or theoretical courses have become clear and distinct, while the advantage to be gained has become so generally recognised that of late years there has been almost a scramble to found new colleges to teach engineering or to introduce such teaching into existing colleges; and most satisfactory to those engaged in the introduction of this subject is the fact that it is from the engineers themselves that the interest and funds

necessary for this work have come. Since 1867 the Owens College has received gifts and bequests from engineers, including those of highest standing in the neighbourhood, of upwards of 150,000*l.*; in the same way at Sheffield and at Leeds, where, as is well known, an engineering school has just been founded by Sir John Hawkshaw and the engineers of the town, and again at Liverpool.

It cannot for one moment be doubted that this movement has been brought about by the conviction of the necessity of an education which, in its subjects and methods of teaching, is much more closely related than was the older system of the Universities, to the actual work which the students may eventually be called upon to undertake; that it is in fact evidence of the appreciation, by those having the greatest experience, of the necessity of higher scientific training for engineers. This is what engineering schools during their struggle for existence have endeavoured to supply. And in spite of the danger which seems to beset all schools as they become older, of falling into the academic or pure—not because it is the most desirable to be learnt, but because it is by far the easiest to teach—in spite of this danger, such in this case is the pressure from without, that it may be hoped the schools of engineering and applied science may be kept up to the mark, both in extending our knowledge of the laws and principles which more immediately underlie the results of practical experience in art, and in teaching the methods of most useful application; and that while encouraged to offer every inducement to the attainment of a sound knowledge of the principles, they will not be allowed to fall into the fatally easy errors of carrying the abstractions of this science outside all possible application, or blocking the way by the insistance on impossible preliminary attainments in mathematics and pure science.

To be hailed as one of the greatest inducements to keeping alive in engineering schools a real scientific interest in the practical work which is going on around them is the introduction of what are now called engineering laboratories, in which students may familiarise themselves with the actual subjects for which the theoretical work is undertaken, and may have placed before them in their most naked forms the data and mechanical actions on which practical achievements depend, and in addition be taught the use of all those instruments and methods of measurement which it is one of the first objects of these laboratories to extend and to perfect, and which measurements are now, as the result of a better knowledge of principles, rapidly displacing the older methods of arriving at conclusions in engineering.

It is to our Continental neighbours that we principally owe the origination of these laboratories as a means of research, but, as a system of instruction distinct from a workshop it owes much to Professor Kennedy, who was, I believe, the first to introduce the testing machine and regular engine trials as part of the regular course of instruction for students in engineering, under the title of a laboratory course. The want of such a course must, however, it would seem, have been severely felt, to judge by the rapidity with which Professor Kennedy's example has been followed in almost all the engineering schools in the country.

It is true that as adjuncts to academic institutions these laboratories can hardly be said to have passed the experimental stage, and it evidently remains to be seen whether when the present arrears of outstanding questions in engineering science are worked up, and the courses of instruction become stereotyped, sufficient variety of work will be found to justify the expense which, both as regards qualified instructors and maintenance of apparatus, must, as compared with the number of students receiving instruction, be greater than is general with academic instruction. At present, however, thanks to the liberality of engineers and their friends, there seems no ground for fear, each new laboratory being furnished with more complete and expensive apparatus than the last. During the erection and fitting of the Whitworth Laboratory in Owens College, which is only now on the verge of completion, it has been very impressing to see the goodwill shown toward the work by everybody who has had to do with it; the ready help of engineers of the greatest experience, like Mr. Rambottom and Mr. Robinson, who have spared neither time nor trouble in giving it the benefit of their experience; also by those who have undertaken the construction of the appliances, particularly Mr. William Mather, of Salford Iron Works, where neither trouble nor money has been considered in

the efforts made to render the engines for the laboratory as perfectly adapted as possible to the very novel and numerous requirements. Taking this particular instance as evidence not only of the general feeling in favour of this movement, but also of the solid support it is to receive, one cannot help concluding that there is a great future before it, and that at last a method has been found of extending and spreading the higher knowledge of mechanical science which commends itself alike to the practical and theoretical.

Everyone who has paid attention to the history of mechanical progress must have been impressed by the smallness in number of recorded attempts to decide the broader questions in engineering by systematic experiments, as well as by the great results which in the long run have apparently followed as the effect of these few researches. I say apparently, because it is certain that there have been other researches which probably, on account of failure to attain some immediate object, have not been recorded, although they may have yielded valuable experience which, though not put on record, has, before it was forgotten, led to other attempts. But even discounting such lost researches, it is very evident that mechanical science was in the past very much hampered by the want of sufficient inducement to the undertaking of experiments to settle questions of the utmost importance to general advance, but which have not promised pecuniary returns—scientific questions which involved a greater sacrifice of time and money than individuals could afford. In recent periods the aid and encouragement which it has been one of the first objects of the British Association to afford such researches has led to many results of the greatest importance, both directly and indirectly, by the effect of example in calling forth aid from other institutions—that of mechanical engineers, for instance, which recently induced Mr. Tower to carry out his already celebrated research on 'The Friction of Lubricated Journals,' the results of which research certainly claim notice as constituting one of the most important of recent steps in mechanical science. Such investigations it is now the function as well as the interest of mechanical laboratories to undertake, and thus what has hitherto been a great obstacle in the path of mechanical progress seems in a fair way to be removed and steady advance to be insured.

To what all this may lead us it is no part of my undertaking to consider, but I venture to end this imperfect address on the progress of mechanical science during the past twenty-six years by what appears to me the most satisfactory conclusion—viz. that to such mechanical progress there is apparently no end: for, as in the past so in the future, each step in any direction will remove limits and carry us past barriers which have till then blocked the way in other directions; and so what for the time may appear to be a visible end or practical limit will turn out but a bend in the road.

The following Papers were read:—

1. *The Iron Mines of Bilbao.*[1] *By* JEREMIAH HEAD, *M.Inst.C.E.*

The author introduces his subject by calling attention to the fact that only one-sixth of the iron ore produced in Great Britain is sufficiently pure to admit of its being used in the manufacture of steel, except by processes involving extra expense.

The steel now annually produced requires the importation of between two and three million tons of hematite ore, in addition to a similar quantity yielded by British mines. The bulk of the imported ore comes from Bilbao in Spain. This trade has grown enormously during recent years, owing to steel having so largely superseded iron. Many British mines are idle, whilst those of Spain continue to increase their production, and blast furnaces in England are now largely occupied in smelting foreign in preference to native mineral.

After referring to previous papers on the Bilbao iron mining industry, the physical features of the district, river, and port are described, and allusion is

[1] Printed *in extenso* in *Industries* for September 16 and 23, 1887; also in *Iron* and *Iron and Coal Trades Review* of September 9 and 16.

made to evidences still existing of the richer veins of ore having been worked by the ancients.

The position of the deposits generally at or near the tops of hills, and their distribution in six principal sub-districts or mining groups, is described, and the leading geological features alluded to. The ore obtained is of four kinds, viz., Rubio (hydrated ferric oxide), Campanil (the same but less fully hydrated), Vena (ditto ditto), and Spathic (or ferrous carbonate). The first-named greatly preponderates over the other three. The origin of the deposits is aqueous. The author here discusses at considerable length the question of how they may have been formed, basing his views on the known action of water containing carbonic acid upon iron and its oxides, and referring to evidence afforded by strong chalybeate springs at the present day. The value of the Bilbao ores for smelting purposes is then considered, in comparison with the ores of Cumberland and the Forest of Dean. Rubio and Campanil differ from each other mainly in that the impurities in the former are of a siliceous, and in the latter of a calcareous nature. Vena ore is very similar in character to Cumberland red hematites. The best Forest of Dean ore appears to be equal or superior to that of Bilbao, but it is unfortunately scarce, and expensive to work. Spathic ore, if calcined, is likely to be of great value in the future.

The Spanish laws and customs in regard to concessions and the royalties payable are then dealt with, and the mining industry in the past is said to have been much impeded by the too great ease with which mere adventurers have been able to secure possession without being obliged to work them. The marvellous development of the district in recent years has been mainly due to foreign capital, enterprise, and energy. Particulars are given of the principal foreign mine-owning companies.

The mining properties are defined by imaginary lines with boundary stones at the intersections. They are worked rather as quarries than as mines, as that term is usually understood, there being no winding or pumping shafts, no water adits, and no pumps. The hills containing mineral are gradually cut away in levels or steps. Tunnels are sometimes driven in at the level of the floor of the deposit, as far as the working face, then a shaft down to it, and side entrances. The ore is poured down the shaft and loaded up into wagons in the tunnel. In quarrying, holes are driven into the working faces with a succession of jumpers, to a depth of 30 feet. A small charge is exploded at the end to form a chamber, into which a large charge is then introduced and afterwards fired. Two or three thousand tons are often brought down in a single blast, and then broken up with wedges, hammers, and crowbars. The impurities being separated, the good mineral is loaded into incline wagons, aërial tramway tubs, or bullock carts, as the case may be. The quarry work is usually let to a Spanish contractor. He employs his own labour, and does the work at from 1*s*. to 2*s*. per ton. The wages paid vary from 2*s*. 6*d*. to 3*s*. 4*d*. per day for drillers, 1*s*. 6*d*. to 2*s*. 6*d*. for labourers and loaders, and 1*s*. to 1*s*. 6*d*. for women and boys.

The working hours are much longer, on an average, than in England, and in summer reach seventy-two hours per week, excluding meal times and rests.

The following table makes comparison between the hours and earnings of the Bilbao and Cleveland miners in the summer of 1886:—

	Hours per week	Daily earnings	Per centage of iron in ore	Cost for labour per hour per man	Ore got per man		Metallic iron got per week per man	Cost for labour per ton of ore	Cost for labour per ton of metallic iron
					per hour	per week			
		s. *d*.		*d*.	Tons	Tons	Tons	*d*.	*d*.
Bilbao . .	72	2 6	50·0	2·5	·5	36·00	18·00	5·0	10·0
Cleveland .	46	5 6 Saturday 4 1½	31·5	8·25	·72	33·12	10·43	11·5	36·5

To win a ton of ore in Cleveland costs more than twice as much for labour as a ton of ore at Bilbao. But to obtain a ton of *metallic iron* in the condition of ore

costs more than three and a half times as much. No wonder that Cleveland mine-owners find it difficult to compete, and that Cleveland blast furnaces are being more and more engaged in smelting foreign rather than native ores.

The characteristics and habits of Spanish as compared with English miners are then noticed. The former are said never to spend money in strikes, gambling, or drunkenness, the three main sources of impoverishment to Englishmen of the same class. They have their weaknesses, however, for whenever bull-fights take place the mines must be closed. From the quarries the mineral is taken to deposits beside railways, or to barges at the river side, by (1) mules and donkeys with panniers; (2) by bullock carts; (3) by shoots; (4) by aërial tramways, and (5) by inclines. The first and second methods are still popular with some mine-owners and under special circumstances. The third is only occasionally applicable. The fourth is much in use, as it is capable of conveying considerable quantities up or down hill and over unequal ground without much interfering with the surface, and at moderate outlay and working cost. Hodgson's and Bleichart's aërial tramway systems are then described; about 2,000 tons per rope per week of seventy-two hours being about the capacity of the former and nearly 3,000 tons of the latter. The cost of Hodgson's system averages 2,000*l.* per mile, and Bleichart's 4,000*l.* Hodgson's is inapplicable where the inclination exceeds one in four, on account of the tubs slipping on the ropes in wet weather. Bleichart's, having a hauling as well as a running rope, has not this disadvantage, and if the inclination exceeds that mentioned it becomes self-acting. Hodgson's system is the cheaper in maintenance as well as in first cost. Both require powerful brakes. The cost of transport is from $7\frac{1}{2}d.$ to 1*s.* per ton per mile in either case, which is much higher than on well-arranged railways or self-acting inclines.

Nine of the principal inclines by which mineral is brought down from mines to deposits are then described. The steepest is that called San Fermin, where the inclination is 80 per cent. The railway wagons are carried on wedge-shaped trucks, running on to them at the top and off at the bottom. The longest and cheapest worked is the Orconera, an incline which is 1,199 yards in length, 1 metre in gauge, with an inclination of 17 per cent. The daily traffic is here 1,500 tons, and the approximate cost of working 6*d.* per ton per mile. Except in one case all the inclines are self-acting. The counterbalanced cradles devised by Mr. J. P. Roe, of Consett, whereby the incline wagons are made to empty their contents automatically into main-line wagons below, is much commended.

The endless-chain system of working inclines, and especially the one made for the Anita mine by Mr. George Lee, is then considered. In a length of 9,867 feet, or nearly two miles, the fall is 1,130 feet. The line is a double one, divided into sections, each having a separate chain; and the direction is twice abruptly changed. The gauge is $1'\ 7\frac{1}{2}''$, and the rails 25 lbs. per yard. On the descending line, tubs holding 10 cwts. of ore run continuously at the rate of three per minute as long as the chains work and are kept supplied; and the empties ascend on the other line at the same rate. The whole works automatically, the speed being controlled by a fan fly, assisted, if necessary, by a powerful friction brake. The cost of working is said to be only 1·261*d.* per ton per mile, and appears to be below that of any other system.

The six principal railways, whereby mineral is taken from the deposits alongside them and put f.o.b. export ship lying at the staithes in the river, are then described. They extend in the aggregate to about 40 miles. They comprise four distinct gauges, the metre gauge with 54 lb. rails and 7-ton bottom door wagons being the most usual. They abound in tunnels, sharp curves, high retaining walls, and gradients up to 1 in 33. The usual speed is from 7 to 14 miles per hour, with trains varying from 20 to 35 wagons each. The average cost of construction is said to have been 50,000*l.* per mile. The charge for loading from deposits, conveying and putting f.o.b. is about 1*s.* 8*d.* per ton. The lines terminate at their river ends in one or more staithes, generally at right angles to the river. The wagons are made either with bottom or with end doors. They run one by one to the end of the staith, and their contents are discharged into a shoot projecting at an inclination into the ship's hold. Each wagon when emptied returns by gravity to

another siding, and is succeeded by a full one. At the Orconera Co.'s Luchana staithes, the height of the approaches was not sufficient to obtain the inclination necessary for shoots. An ingenious arrangement, devised by Mr. Roe, was therefore substituted. The staith terminates in a tower from which is suspended one end of a platform, the other end being jointed to the staith at the level of the rails, draw-bridge fashion. The platform has a discharging hole in the middle, and to the underside is fixed a telescopic counterbalanced trunk, with doors at the bottom. This is lowered or raised by a load of ore or by the balance weights controlled by a brake respectively, the object being to introduce the first few loads of ore gently, lest the bottom of the ship should be damaged. The Orconera Co.'s shipping arrangements are considered the best in the port. About 150 tons per staith per hour is the highest rate attained.

After some observations on wasteful selection, caused by the pressure of consumers and others interested in maintaining a high percentage of metallic iron in all ore exported, the author gives figures showing the cost of raising and putting it f.o.b. to be usually from 4*s.* 11*d.* to 5*s.* 6*d.* per ton, but he thinks it is done in some cases for less.

He then enters into the question of probable duration. The area of the known deposits is about 7,000,000 square metres, equal to 12,600,000 tons per metre of average depth. The quantity still remaining is estimated by different authorities at from 50 to 200 million tons, and the duration at from $12\frac{1}{2}$ to 50 years.

The next question touched upon is whether the ore of Bilbao can be more cheaply smelted into pig iron on the spot or in England. Inasmuch as two tons of ore at 5*s.* per ton for freight are carried in the latter case, against one ton of coke at 5*s.* per ton for freight in the former case, it would appear that Bilbao has the advantage. An import duty of 10*d.* per ton on coke is balanced by the cheaper labour of Spain. England has, however, better shipping facilities to most neutral markets. Export statistics are given showing the following results, viz.:—That at present hematite pig iron for British consumption can be obtained more cheaply by importing ore, rather than pig iron, and the same applies to the north of France. The British export trade, in the same article, has not yet been affected by Spanish competition, as regards America, Holland, Belgium, Germany, and Austria. But to Italy, Southern Russia, and Mediterranean ports generally, the Bilbao pig-iron exports have increased nearly 300 per cent. since last year, and Great Britain seems no longer able to compete.

In conclusion, the author tenders his thanks to the writers of the papers he has consulted, and to various gentlemen connected with the iron-mining industry, who have afforded him valuable assistance.

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2. *Improvements in the Manufacture of Portland Cement.* *By* Fredk. Ransome.

The author described the method up to the present time generally adopted in making Portland cement, which he designated the 'kiln process,' and he pointed out the several defects that he considers inherent in it. He then proceeded to describe a method that he has devised and patented which is free from the defects alluded to. Its main features consist in burning the materials of which the cement is composed in the form of powder instead of in lumps, and he demonstrated the economy of capital, space, time, fuel, &c., insured thereby.

He then gave a statement of facts bearing upon these results, describing actual working details, illustrating his method by diagrams of the apparatus as devised, and exhibiting samples of the materials employed, with sections of some briquettes produced therefrom, with a table of the tensile strains to which they have been subjected.

He concluded by alluding to further developments and the utilisation of other materials capable of producing excellent cement, which could not be accomplished economically by the 'kiln process.'

3. *The Severn Tunnel.* *By* T. A. Walker.

After referring to the inconvenience caused to traffic between Bristol and the towns of South Wales before the introduction of railways by the broad tidal estuary of the Severn and the détour which it necessitated in the Great Western Railway, the author mentions that a bridge was designed by Sir J. Fowler to cross the river at Chepstow; but this project was subsequently abandoned, and in 1862 the company established a steamboat ferry at New Passage which was met by trains at either side. The tides, at times attaining a height of 45 ft., rendered this arrangement very inconvenient, and in 1871 Mr. C. Richardson deposited plans for the tunnel which has since been constructed.

It is situated about three-quarters of a mile south of the line followed by the steamboats, where the river is $2\frac{1}{4}$ miles wide at high water, and the deep water channel is cut through hard Pennant rock of the Coal Measures. The Act was obtained in the Session of 1872, and the Great Western Railway Company commenced the works in February 1873. The new line, as designed and approved by Parliament, consisted of a railway descending from the South Wales Railway for about four miles on a gradient of 1 in 100 to the deepest part of the river, known as 'The Shoots,' and ascending from that point by the same gradient of 1 in 100 to join the Bristol and South Wales Railway near Pilning station, the total length of the railway being about eight miles, and the length of the tunnel four and a half miles. The thickness of rock above the crown of the arch was in one place 15 ft., in another 30 ft., but generally from 80 to 100 ft. The company made numerous preliminary experiments with a view to ascertain the nature of the work to be undertaken, during which considerable difficulties were experienced, owing to the large quantity of water met with. These were continued till October 1879, when the heading on formation level then being driven westward from the Sudbrook shaft tapped a great spring of fresh water which proved to be in vastly greater volume than the pumps could master, and in twenty-four hours the whole of the works in connection with that shaft were drowned. The pumps at the other shafts also proved unequal to the quantity which percolated from the adjoining heading, and the works were brought to an entire standstill at the end of October 1879.

The heading under the river had been advanced so far that only 130 yards intervened between that being driven from Sudbrook eastwards and that driven from the Gloucestershire side westwards. At this stage Sir John Hawkshaw, in conjunction with Mr. Charles Richardson, took entire charge of the work, and the contract was let to the author in December 1879.

After narrating the various steps taken to remove the large quantity of water in the works and describing the difficulties met with, the paper states that by November 1880 the depth of water was reduced to 30 ft. on the bottom heading. As the progress was then particularly slow, and it was known that there existed at about 1,000 ft. under the river from the shaft an iron door, by which the water flowing from under the river could be stopped from coming to the shaft, the author sent one of the divers, named Lambert, with two assistant divers to help him, to try to shut this door. As the length of hose he would have to drag with him to supply air to his helmet was 1,200 ft., it was impossible for him to attempt this without assistance. One diver was stationed in the bottom of the shaft to pull down the hose and feed it forward into the heading. Lambert, with another diver, then proceeded about 500 ft. up the heading, and then Lambert alone, the other man remaining at the end of 500 ft. to drag forward and feed to Lambert the floating air hose as he advanced. By this means Lambert was enabled to reach within about 100 ft. of the door, but the friction of the hose on the roof of the heading then became too great for his powers, and though he sat down and pluckily began to draw the hose forward, and so proceed a few feet at a time, he was at last compelled to give it up in despair and to return to the shaft defeated.

Wearing the Fleuss diving dress, however, Lambert again proceeded on November 8 to shut the door. He reached the door in safety, pulled up one of the rails of the tramway which passed through it, but then, no doubt overcome by

the novelty of his situation, he returned to the shaft without shutting the door. On the 10th he made another attempt, reached the door in safety, passed through and let down a flap valve upon a pipe which passed under the door, pulled up the other rail, closed the door, and then screwed round the rod of a sluice valve on a pipe which passed under the door on the opposite side from the one which was protected by the flap valve, and returned in triumph to the shaft.

He was absent on this journey one hour and twenty minutes in total darkness up a small heading, in which he met with iron skips standing on the rails, or overturned by the side of them, lumps of rock or falls from the roof, enough to make the bravest man nervous. It was not, however, till December 6 that the water was all out of the iron pit, and there was then only 2 ft. of water in the heading under the river. On the 7th a foreman walked up the heading to the door which Lambert had closed, and found that all the work had been thoroughly done, but that the sluice valve having a left-handed screw, Lambert, instead of closing the sluice, had opened it wide, and that accounted for our obtaining no relief from the shutting of this door. By closing the sluice valve we obtained immediate relief, and were able from that time forward to keep the heading dry and to have always one pump in reserve.

On December 13, 1880, Mr. J. Clarke Hawkshaw and the author, with the principal foreman of the miners, went into the heading into which the great spring had broken, and were able from some little distance to see the point where the timbering had given way, and where the water was pouring in, and arranged for the building of a head wall across the heading to stop back the water from the spring.

As soon as possible the heading under the river was examined. So far as it was in the Pennant sandstone it was in a fairly good condition, but where on the ascending gradient towards the Gloucestershire side, it passed from the Pennant sandstone to the red marl, the timber had given way, and a great cavity existed nearly 20 ft. high, above the roof of the heading, into which there was great fear that the river itself might break.

The total number of men employed when the works were progressing most actively was about 5,000.

In the construction of the tunnel itself there were no exceptional difficulties except those arising from the quantity of water.

The mining and lining of the tunnel proper was commenced early in the year 1881, and after many difficulties and unforeseen obstacles the whole was completed in April 1885.

Immediately after Sir John Hawkshaw had taken charge of the works as chief engineer, he decided to lower the gradients under the river by 15 ft.

On October 10, 1883, being within a week of four years from the time the tunnel had been drowned by the great spring, the heading on the new gradient, 15 ft. below the existing heading, tapped nearly at the same point the same spring in much greater volume, but by again sending up the diver the door was closed in this heading, into which the spring had broken, and the works again cleared of water.

Only three days after this spring flooded the works, one of the largest pumps in the next shaft broke down, and that shaft was also filled with water, and on October 17 a great tidal wave passed up the Bristol Channel, submerging all the low-lying parts of Cardiff and Newport, drowning hundreds of cattle in the marshes near the estuary of the river, passing through the houses inhabited by the men near Caldicot, first reaching the engine fires at the Marsh pit and extinguishing them, and then flowed down the Marsh pit in a cataract 110 ft. deep, imprisoning below eighty-three men who were at work upon the night shift. Being totally dark, and the whole of the district around the shaft for a width of a quarter of a mile being from 3 ft. to 4 ft. under water, it was with great difficulty that assistance could be sent to the men; and the water continuing to rise in the finished tunnel and the bottom of the shaft till it reached within 8 ft. of the crown of the arch, the men who had retreated before the rising water in the tunnel had reached a stage in one of the partially finished lengths, where they

remained in great terror till those upon the surface succeeded in stopping the water from flowing down the shaft, when a boat was obtained and the men were rescued. These three disasters occurred within one week.

The bricks used in the tunnel were all vitrified bricks from Staffordshire or Cattybrook, near Bristol, or made upon the ground from shale excavated from the tunnel itself, which made a stronger brick than either Staffordshire or Cattybrook. The whole of the brickwork was set in Portland cement mortar mixed with washed sand in the proportion of two of sand to one of cement. The laying of the permanent road through the tunnel was completed at the end of August 1885. The water was finally shut out from the works on August 11, 1885. The first passenger train passed through the tunnel on September 5, 1885.[1]

The water from the great spring, which was blocked out of the tunnel on August 11, began to rise through the ground till on October 24 it showed on the pressure gauges fixed in the brickwork a pressure of $53\frac{1}{2}$ lbs. on the square inch. When the pressure reached this point the bricks began to fly with reports like pistol shots, and to break, so that considerable quantities of water entered the tunnel. The pressure rose at one time to 57 lbs. on the square inch, when Sir John Hawkshaw decided that it would be unsafe to work the tunnel under so great a pressure, and arrangements were made to pump the spring permanently.

On November 22, 1886, the line was inspected by Colonel Rich, and it was finally opened for passenger traffic on December 1. During the six months that have since elapsed not the slightest hitch has occurred in working the tunnel. The speed of the trains has often been as much as a mile a minute.

The ventilation has been perfect, and the relief to the traffic between South Wales and the south-west of England has been very sensibly felt; this traffic will no doubt, with the accommodation afforded by the tunnel, be greatly increased when the trains from London to South Wales run direct through the tunnel, instead of, as at present, by Gloucester.

FRIDAY, SEPTEMBER 2.

The following Papers were read:—

1. *On certain Laws relating to the Régime of Rivers and Estuaries, and on the possibility of Experiments on a small scale. By* Professor OSBORNE REYNOLDS, *LL.D., F.R.S.*—See Reports p. 555.

2. *Improvement of the Access to the Mersey Ports.*[1] *By* W. SHELFORD, *M.Inst.C.E.*

The author, whose attention was specially directed to the condition of the Liverpool bar during the parliamentary inquiries relating to the Manchester Ship Canal, after referring briefly to the past history of the bar, draws attention to the geographical situation of Liverpool Bay as having an important bearing on the proper mode of dealing with the bar.

The tide in Liverpool Bay has a great vertical range,[2] and the capacious natural tidal reservoir of the Mersey causes a strong local current into and out of the bay; but there is no external or alongshore current independent of this capable of removing heavy detritus to a distance, although the character of the bottom shows that the finer suspended matters brought down by the river are carried away and deposited in deep water.

The reasons for the absence of such an external current are evident, since the bay is not only considerably landlocked by the Welsh and Lancashire coasts, but

[1] The paper has been printed *in extenso* in the *Liverpool Daily Post* of September 3, 1887.

[2] Thirty feet at springs.

almost directly opposite to it is that part of the Irish Sea where there is no perceptible current, owing to the meeting of the branches of the Atlantic tidal wave which have passed round the north and south of Ireland.

Admitting the disadvantage of the absence of a transporting current, the author considers the great volume of the local tidal flow sufficient, if properly directed, to maintain a navigable channel at the bar, which would greatly reduce the delay and risk to shipping caused by the present want of depth over it, and thus materially benefit the trade of the Mersey.

The fact that the same tidal flow where directed by natural sandbanks does now maintain a channel about 6,000 feet wide at low water springs, and from 24 to 48 feet deep for over nine miles from New Brighton, is adduced as a proof that the quantity of tidal water is sufficient to maintain such a channel.

That it fails to do so now where the bar occurs (*i.e.*, from $9\frac{1}{2}$ to 11 miles from New Brighton) is sufficiently explained by the increase of the effective width of the channel at the bar from 6,000 to 23,000 feet.

The author finds that the sectional area of the low-water channel from New Brighton to the bar is tolerably constant, as might be expected from its being formed and maintained by a constant flow of water through yielding materials.

He accounts for the increase of 30 per cent. in the effective area at the bar itself by the eddies and irregularities in the flow which attend so great an increase of width, and by the tendency of the flood tide to break through the south side of the horseshoe ridge of the bar.

The author considers that a channel formed through the bar by dredging would not be self-maintaining on account of this tendency of the flood tide to break through the sides, and so to keep open subsidiary channels which would rob the main channel of the full scouring power of the ebb.

In order to enable a permanent channel to be made, or at least maintained by natural scour, the author would restrict the width of the low-water channel over the bar by extending the natural sandbanks seaward.

To do this he would deposit mounds of rough stone, protected where necessary by larger blocks.

The proper direction in which the channel should be fixed by the works, and their height and distance apart, can only be determined by a minute examination of the present channel and tidal currents, but the present direction of the bar channel appears particularly favourable, and it is not anticipated that the works need be carried to a greater height than four feet above low water of spring tides.

They would leave undisturbed the present navigation of the Rock and Formby Channels, and they would not involve a disturbance of the natural regimen of the bay.

The communication is illustrated by a model of the bay, extending from Liverpool to the deep water outside the bar, which shows clearly the advantage of the present line of the channel as an access to deep water, and the prevalence of shallows and shifting sands on the south side of the Burbo banks which render extremely undesirable the opening of a new channel in that direction.

The possibility of such an occurrence has long been recognised, and in the author's opinion is a danger to be carefully guarded against in the interests of the Mersey ports.

3. *The Manchester Ship Canal.* *By* E. Leader Williams.

The author mentioned that, after unsuccessful attempts in the years 1883 and 1884, Acts of Parliament have been obtained in the sessions of 1885, 1886, and 1887, which give the Manchester Ship Canal Co. power to construct a large ship canal from the deep water at Eastham, near Liverpool, to Manchester.

The Board of Trade having certified that the conditions in the Acts relating to capital have been complied with, the contract for the whole of the works has been let to Mr. T. A. Walker, of Westminster, and the construction of the canal will be commenced as soon as the arrangements, now in progress, for the purchase of the lands required are completed.

The canal will be of greater bottom width than the Suez, Amsterdam, or any other ship canal, and it will absorb the whole of the waters of the rivers Mersey and Irwell and their tributaries between Manchester and Warrington.

From Eastham to Warrington, a distance of twenty miles, the tidal water of the Mersey estuary will be impounded on one level by large entrance locks at Eastham.

The depth of the water in the canal will vary with the height of the tide, but will never be less than twenty-six feet. The minimum bottom width of the canal will be 120 feet, or nearly forty feet more than the Suez Canal.

Above Warrington large ship locks will be constructed at Latchford, Irlam, and Barton to raise the canal to the level of Manchester. The total length of the canal will be thirty-five and a half miles.

Docks, quays, and basins will be constructed at Manchester, Barton, Warrington, Partington, and Weston Point.

The existing docks at Runcorn (now the property of the Manchester Ship Canal Co.) are connected with the ship canal, and will afford the means of developing the trade of Staffordshire and the Potteries.

The docks at Weston Point and Ellesmere Port are on the ship canal.

The Bridgwater canals recently purchased by the Ship Canal Co. are in connection with the proposed new docks at Manchester, and all the inland canals are in direct communication with the Bridgwater Canal, which will also join the ship canal at Runcorn and Barton.

A model of the canal was exhibited, and reference was made to a larger model on view at the Manchester Jubilee Exhibition.

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4. *Experiments on the Mechanical Equivalent of Heat on a large scale.* *By* E. A. Cowper *and* W. Anderson.—See Reports, p. 562.

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5. *What is a Drought?* [1] *By* G. J. Symons, *F.R.S.*

After referring to the difficulties he experienced more than twenty years ago in arriving at a definition of a 'rainy day,' and, at a later period, in regard to drought, the author stated that in 1880 he adopted a classification in regard to droughts which has been generally used up to the present time: it is as follows:—

Absolute droughts.—Periods of fourteen or more consecutive days absolutely without rain.

Partial droughts.—Periods of twenty-eight or more consecutive days in which the total rainfall does not exceed 0·25 inch.

These definitions include the two elements of quantity of rain and of duration, and neither opinion nor imagination can affect them. They have, however, no connection with or resemblance to that which engineers, who are familiar with water-works construction, consider as a drought. And the object of this paper is to try and find a common ground whereby the records of the nearly three thousand observers of rainfall in the British Isles may be utilised in the form most useful to engineers.

Among water engineers, however, droughts of 140, 160, 200, and even 240 days are recognised. It is quite certain that these are not 'absolute' nor even 'partial' droughts, according to the definition that we have laid down, because even in a dry place like London a register for thirty years gives no 'absolute' drought of more than twenty-eight days, nor 'partial' drought of more than forty-one days. It is therefore evident that the drought of the engineer is something much less severe than even my 'partial' drought.

The author then discusses this discrepancy, and concludes with a suggestion which might meet the requirements of engineers; at any rate, it will afford something to criticise.

Long droughts.—Periods of not less than sixty days with a total rainfall of less than 2·00 in.

[1] *Monthly Meteorological Magazine*, vol. xxii. (1887), p. 121.

SATURDAY, SEPTEMBER 3.

The following Papers were read:—

1. *The Forth Bridge Works.*[1] *By* A. S. Biggart.

The erection of the main steel piers of the Forth Bridge is now practically completed. The only exception from the lines indicated in my paper two years ago requiring to be noticed is the case of the internal viaduct, which was built in position instead of being raised in a completed state.

The working of the plant proved satisfactory in all respects. On some occasions the piers and platforms were raised as much as 48 feet within eight days.

A point of vital importance is the starting of the various members of the piers at their proper angle. A slight movement at the point of fixture may be found to produce an initial stress as great as the full working stress. Hence, in setting out, not only had great care to be exercised, but many points involving careful calculation and supervision arose.

Erection of Cantilevers.—This was commenced before the piers had attained their full height. The bottom member was built on the overhang system, at first, by means of an ordinary crane. Resort was afterwards had to a cage placed at the end of each tube within which the men can work. This cage is secured to rings encircling the tube, and as it is built of exactly similar sections, it can easily be moved forward by removing the two back sections and placing them in front. Above the cage is placed a hydraulic crane for manipulating the beams and plates brought out on a tramway running alongside the tube.

When fully 100 feet out support was given to the tube by carrying up temporary ties to the main piers. Two kinds of ties are employed, the main object of the one being to assist in the erection of the other, and afterwards serve to carry it. On the completion of the ties the platforms for erecting Bay No. 1 were built immediately over the bottom member, and afterwards raised into position. Subsequent raisings are accomplished by hydraulic jacks. From these platforms the struts, ties, and other parts of the bridge are being built.

A most interesting and important part of the work consists in observing and providing for the vertical movements and stresses of the various members of the cantilevers. Those of the bottom member are alike numerous and intricate. First there is a deflection due to the tube's own weight and that of the plant; then an upward rise from the pull of the link ties; an upward again, occasioned by the weight of the other tie and its supports hanging on the link tie; another upward caused by the hydraulic rams raising the tube; a fall due to the weight of permanent material of the cantilever being built in position; a rise when the permanent ties will be connected, and finally a gradual fall as the cantilevers are built out. These form seven clearly marked movements to be considered and provided for, the ultimate aim being to leave in the tube only the normal initial stress.

The experience gained from the work of erection already completed has assisted greatly in enabling us to prepare the plant for the future work. Thus, after full consideration, Sir John Fowler, Mr. Baker, and Mr. Arrol feel warranted in adopting another principle for the erection of the next bay of the cantilevers. Cranes, some at high altitudes above their work, and light cages and platforms, will be the distinguishing feature of the new method.

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2. *The City of London and Southwark Subway.*[2]
By J. H. Greathead, *M.Inst.C.E.*

The Subway Company was incorporated by an Act of Parliament in 1884, and authorised to construct a double line of subway from King William Street to the

[1] Published *in extenso* in *Industries.*
[2] Published in the *Engineer,* Oct. 7, 1887; and in *Industries,* Oct. 21, 1887.

'Elephant and Castle'; and by an Act of the present year the company has been invested with power to extend the line to the Clapham Road at Stockwell. The subway is intended to give better access to and from the City for the densely populated and rapidly growing districts on the south side of the Thames, now only directly served by omnibuses traversing crowded thoroughfares, including London Bridge.

Rather over three miles in length, the 'up' and 'down' lines will be carried in separate tunnels placed at such a depth under the surface of the roads as to avoid all interference with sewers and pipes. Where not under the river the subway will be under the roads entirely. At each station, of which there will be six, powerful hydraulic lifts will be provided in addition to the stairs.

The traction will be by stationary engines and endless cables, similar to the system adopted on cable tramways. By this means light trains can be economically run at short intervals in place of the heavy locomotive trains now run on the underground railways.

The whole power, both for traction and lifts, will be placed at one station about the middle of the line.

The carriages, which will be very commodious, are to be of the longitudinal type, similar to Pullman and ordinary tramway cars.

The first tunnel was commenced on the north side of the Thames in November last year. By the beginning of September it had been driven under the river Thames and the roads for a distance of 1,600 feet. The second tunnel, commenced at a later date, was progressing at the same rate. The mode of construction is very simple. An overlapping 'shield' at the advanced end of the tunnel, forced forward by hydraulic pressure as the material is excavated from before it, enables six rings of cast iron, each 1 foot 7 inches long, to be built up under cover of the overlapping cylinder every day. As the shield is advanced an annular space is left outside the iron tunnel lining, and this is filled with semi-fluid cement by means of an apparatus worked by compressed air, which is fully described in the paper. Arrangements for tunnelling through soft or loose water-bearing material were also described, with illustrations and a model.

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3. *On a High-speed Steam or Hydraulic Revolving Engine.*[1] *By* Arthur Rigg.

The author describes results of further experience with a new description of revolving engine, of which a general account was given at the meeting of the Association last year.

The engine consists of several cylinders, all of which revolve on a common centre, while their pistons are connected with crank-pins on the rim of a wheel which turns on a different centre. By this arrangement there is obtained a movement of the pistons within the cylinders, corresponding in effect with a true reciprocation; and as all the pistons and cylinders are balanced with each other, there is no loss of power or excessive vibration such as is found to accompany ordinary reciprocation; and engines of this revolving type can be driven at very high speeds with a perfectly steady and uniform motion.

One hydraulic engine of this class has been running for some months in London, driving a dynamo and 100 incandescent lights from the pressure mains of the Hydraulic Power Supply Co. The pressure is 700 lbs. per square inch, and this particular engine makes 250 revolutions per minute, developing 13 horse-power, with 33 gallons of water per minute; this corresponds with a duty of 80 per cent.

It is governed by causing the piston-stroke to vary; and this method of regulation maintains a uniform speed, although the power may vary, so that the lights remain quite steady, however many be switched on or off.

A similar engine has been driving a capstan at the Millwall Docks, London. It can be reversed or give any variation of power in either direction of motion.

[1] Published *in extenso* in *Iron*, Sept. 9, 1887.

Steam engines of this revolving type have been in continuous regular work for more than a year, and much useful experience acquired in their use.

In these engines governing is accomplished by varying the rate of expansion, with a result that great economy in fuel is secured with a high speed. Their dynamic balance is perfectly adjusted; they work smoothly and quietly, and drive with remarkable regularity.

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4. *An improved Steel Railway Sleeper, with Chairs pressed out of the Solid.* *By* HENRY WHITE.

The author's object has been to produce out of steel plate, or, still better, strip, rolled to a trough-like section, a sleeper which shall have chairs, solid with it, to suit any ordinary type of rail, thus avoiding bolts and rivets.

To accomplish this he has special dies, which are fitted to a suitable hydraulic or other press, or pair of presses, if it be desired to make both chairs at the same time. The trough steel being first cut to the required length, is heated and inserted between the open dies of a first or preliminary press or pair of presses, which roughly form two corrugations at each end corresponding with the jaws of the chairs. The metal for this is gathered up endwise, thus shortening the original length of the piece of steel operated on. Another heat being taken upon it, the partly made sleeper is placed between the dies of the finishing press or presses, which give the jaws their final form. The lower dies in this case have two hinged pieces which project upwards, and when the upper ones descend they close inwards, causing one of each pair of jaws to assume the 'undercut' form necessary to fit the rail and hold it firmly in its place. A loose piece resembling the lower part of the rail is inserted between the jointed pieces, to form a resistance-block for them to close against.

The paper is illustrated by a sectional drawing showing the action of the dies, and also by a model made on the scale of $1\frac{1}{2}$ inch to the foot. It is claimed that sleepers so formed give a larger base to the rail, hold it more firmly, and are stiffer than any others hitherto used.

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5. *Specimens of Steel produced by skidding Railway Wheels.*[1] *By* JEREMIAH HEAD, *M.Inst.C.E.*

Where a heavy gradient or incline occurs upon a railway, necessitating the frequent and severe use of brakes to prevent too rapid descents, pieces of metal of a peculiar form resembling the leaves of ferns have frequently been found alongside the rails.

Close examination of the specimens will satisfy the observer:—

1. That though differing in size and colour, they have all the same origin and the same cause.

2. That being found on steep inclines only, they are probably due in some way to the action of the brakes of descending trains.

3. That being (as will hereafter be shown) of steel, they must have come from the tyres or rails, and not from the brake blocks.

4. That in assuming their present form, they have undergone considerable pressure, and at a temperature higher than ordinary.

It is the purpose of the paper to consider, and determine if possible, how these specimens have been produced, and how far their existence has significance; either practically as an element of destruction or danger on railways, or scientifically as indicating what may happen when the power of metals to resist pressure or abrasion has been exceeded. The following table of analyses made by Mr. Routledge, chemical analyst to the North Eastern Railway Company, makes a comparison between the composition of the specimens and that of tyres and rails.

The author proceeds to give the opinions of certain authorities connected with

[1] This paper will be found *in extenso* in the *Engineer* for Sept. 9, 1887, and also in various other technical journals.

railway working, or otherwise interested in the matter, as to the origin of the specimens. The prevalent opinion seems to be that they were torn from the *tyres* of skidding wheels, rather than from the rails upon which they skidded during the descent of trains upon inclines. Mr. Routledge, however, having regard to the evidence of the analyses, is of opinion that they have come from the *rails*, and not from the tyres. It appears that the steel of which the tyres analysed were composed differs from that of which the rails were made by higher silicon and lower manganese, which is not the case with the specimens. The presence of tin in the latter is somewhat remarkable, but that element has sometimes been found in pig iron.

	Specimens	Tyres			Rails			Greatest resemblance to
Column No.	1	2	3	4	5	6	7	8
		from	to	average	from	to	average	
Phosphorus	·06	·04	·05	·046	·03	·07	·05	Rails
Sulphur	·07	·01	·09	·062	·04	·14	·07	Rails
Carbon	·57	·24	·63	·486	·35	·60	·475	Tyres
Silicon	·09	·16	·33	·274	·04	·10	·07	Rails
Manganese	·79	·21	·52	·390	·80	1·00	·90	Rails
Tin	·07	—	—	—	—	—	—	—
Iron	98·35	—	—	98·742	—	—	98·435	Rails
Total	100·00			100·00			100·00	

The author thinks, however, that inasmuch as blows, or charges, of steel are often run indiscriminately into ingots for rails or for tyres, and as it cannot be stated certainly what was the composition of the identical tyres and rails concerned in forming the specimens analysed, it is scarcely prudent to found any strong argument upon these analyses.

The practical lesson taught by the specimens is that wheels should never be skidded. But, on the other hand, trains, whether passenger, goods, or mineral, should always be retarded by braking a sufficient number of wheels to effect the desired object, with a pressure somewhat short of skidding. Skidding wheels is indeed a barbarous and ineffectual attempt at retardation, whilst it is a most effectual cause of disintegration.

The specimens looked at from a scientific point of view are interesting. Their colour indicates that they have been formed at a high temperature, as they have clearly all been originally coated with magnetic oxide (Fe_3O_4). The comparatively large body of metal forming the rail and its continual presentation of new surfaces during skidding make it improbable that it could have reached any high temperature; whereas skidded wheels might easily present the same surface long enough to accumulate heat locally to a greater extent than could be, *pari passu*, dissipated by conduction. The multitude of folds which appear in all the specimens, and the tendency to spread into various forms, seem to indicate that under the pressure to which they have been subjected the metal has 'flowed' with great freedom.

Reviewing the evidence obtained so far, the author inclines to accept the following conclusions, viz.:—

1. That the pieces have come from the *tyres* of skidding wheels, and *not* from the *rails*.

2. That they were produced at a sufficiently high temperature for the formation of magnetic oxide, *i.e.*, at a *red heat*.

3. That they were forced out from *behind* the skidding wheels (the folds being on the *under* side) until from their accumulated length and weight they fell off.

4. That the only way to avoid the destructive action which they indicate is to brake more wheels to an extent short of skidding.

MONDAY, SEPTEMBER 5.

The following Papers were read:—

1. *On Copper Wire.* By W. H. Preece, *F.R.S.*

Four copper wires have recently been erected between London and Dublin. The aërial portion was built with No. $12\frac{1}{2}$, ·097 inch in diameter, weighing 150 pounds per mile, having a specified resistance of $6·05^{\omega}$ per mile and a tensile strength of 490 pounds, or $29\frac{1}{2}$ tons per inch.

The resistance per mile when erected was $5·695^{\omega}$ at 30° F. The capacity per mile was ·01319 microfarad, and the insulation per mile was 70 megohms at 30° F.

Copper wire is subject to strict inspection. It is gauged and tested for ductility and for tensile strength. The wire now supplied exceeds the specified demand. Its tensile strength equals 30·6 tons per square inch, and its conductivity is 98 per cent. of that of pure copper. An entirely new method of wiring has been adopted. The wire is drawn up and regulated to its proper stress by a dynamometer. The factor of safety is 4. A table is given showing the sags and stresses with varying spans and temperatures for iron and copper. The wire is bound to the insulator by finer copper wire, and the joints are the form known as the 'Britannia' and soldered. It requires very careful handling to avoid indentation. Scratches and kinks are very injurious. It is practically free from the throttling effect of electromagnetic inertia, and by the reduction in resistance and capacity it has trebled the efficiency of aërial wires. Various copper wires are now being erected.

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2. *Fast Speed Telegraphy.*[1] By W. H. Preece, *F.R.S.*

The author explained that the object of his paper was to describe the evolution of the system of fast speed telegraphy since it left the hands of Wheatstone and Stroh. The following table illustrates the progress made:—

Year	Words per minute	Speed to Ireland
1870	80	50·3
1875	100	70
1880	200	150
1885	350	250
Now	600	462

These results have been the consequences of: (1) Greater perfection of apparatus; (2) the elimination of electromagnetic inertia; (3) the improvement of circuits; (4) introduction of high-speed repeaters.

A complete set of automatic instruments consists of: (1) the perforator, which punches a strip of paper with holes on the principle of the Jacquard loom, so as to regulate the number, order, and rate at which alternate currents of electricity are sent along a wire by (2) the transmitter, which is the automatic part of the apparatus, sending along the line those currents which at the distant end are recorded as words in the form of dots and dashes, replacing the slow and uncertain manipulation of the hand; (3) the receiver, which is an ink writer of extreme delicacy and great rapidity, recording the words in the Morse character.

As the speed of transmission increased, it was found that one great source of trouble was the sparking at the points of contact, which dirties them by disintegrating the metal. Small condensers of $\frac{1}{10}$ microfarad capacity have been applied, and the evil thereby considerably modified; but it has been still further reduced by switching out the galvanometer while the transmitter is at work, for sparking is principally due to the presence of electromagnetic inertia in the apparatus.

[1] Published *in extenso* in *Industries*, vol. iii. p. 296.

It was thought at one time that the speed of working was limited by the retardation of the line circuit, but a careful inquiry into the phenomena of electromagnetic inertia ('Journal of the Society of Telegraph Engineers,' 1887, vol. v. p. 27) led to the conclusion that the principal source of slowness was in the electromagnet. Every electromagnet has thus a time constant which determines the rate beyond which it cannot work. This time constant can be obtained only by experiment, for it depends on the quality and quantity of iron used, on the form of the core, on the resistance and quality of insulated copper wire, on the number of turns, and on the way they are wound. After numerous experiments it was found that this effect of the electromagnet could be eliminated by the use of a shunted condenser, and the introduction of this instrument has had the most marvellous effect on the speed of working. It has entirely eliminated any hindrance caused by the electromagnet, and now the only cause of slow working is the mechanical efficiency of the apparatus and the condition of the circuit.

Four hundred and fifty words a minute are now obtained with ease on circuits two hundred miles in length, and on some circuits six hundred words per minute are reached; but four hundred and fifty are more than can practically be coped with, and therefore at present the apparatus exceeds in efficiency the capacity of the staff; but this speed rapidly falls off as the retardation of the circuit increases, and while it is possible to work at the highest speed between London and Leeds, only one-fourth of this speed is practicable to Glasgow. If, however, we place at Leeds a repeater, which will respond to and relay on these frequent currents, we ought to get the maximum speed to Glasgow, and this is done by the high-speed repeater. These instruments are very extensively used. There are special relay offices at Haverfordwest, Nevin, and Anglesey to provide full speed to Ireland. The speed to Ireland in 1870 was fifty words per minute. It is now four hundred and sixty two words—a ninefold advance. Leeds, Manchester, Bristol, and Preston have also special relay rooms, and there are 101 repeaters in use.

The introduction of high-speed repeaters and the use of shunted condensers have marked epochs in the evolution of telegraphy as eventful as the introduction of duplex working or of the telephone.

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3. *Underground Conductors for Electric Lighting, &c.* *By* Professor G. Forbes, *M.A., F.R.S. L. & E.*

The author has designed the proposed system to fulfil several important conditions.

1. The conductors and their insulation should be economical in construction.
2. They should be protected from injury by a trough or casing.
3. This trough should be of small cost and its merits must have been well tested.
4. The trough must be capable of carrying conductors at several different potentials.
5. It must be possible gradually to add to the conductors as the consumption of electricity in a district increases.
6. An easy means must be provided for taking branches from the mains into houses.
7. An easy means must be provided for leading the conductors round gas and water pipes, and other obstacles.

The first condition can best be secured by having bare copper-wire conductors and air-insulation. The second and third conditions by using ordinary cast-iron gas pipes whose qualities are thoroughly well known, and whose laying and repairing and keeping water-tight is everyday work in every town in the country.

The fourth condition is attained by having porcelain insulating discs, two in each cast-iron pipe. Each insulator has as many holes through it as there are different potentials to be maintained. These porcelain discs are supported on the iron pipes only at a few points, the intervening spaces allowing drainage in the cast-iron pipes, and also permitting dry air to be forced through a system of pipes.

The fifth and sixth conditions are attained by the special peculiarity of this invention, which consists in using thin split copper tubes with a quarter-inch gap at the split. These are each six inches longer than one of the iron pipes. By pinching the end of one of these tubes and inserting it in the end of another and continuing the process, a long continuous tube can be made for carrying the bare copper-wire conductors. These continuous tubes pass through the holes in the insulators. The number of copper wires can be added to as the requirements of a district increase. When two-thirds full these wires are all withdrawn and a bare wire cable filling the whole space of the tubes is drawn through. The wires are drawn through from man-hole to man-hole. A man-hole is placed at each corner of a street and serves also as a sump for pumping out accumulations of water. When it is required to connect a house to the mains the iron pipe is drilled and tapped with a one-inch hole. Insulated wires are soldered to the copper tubes of the required potentials, and are led to the houses through one-inch gas pipes, which are screwed into the hole tapped in the cast-iron pipes. It will be noticed that the split tubes do not act primarily as the conductors of the main current, but mainly as a support for the conductors, and secondarily by contact with these as a means of connection to the houses, leaving the wires free to be removed or added to.

The seventh condition is to provide for getting round an obstacle. This is best done by having hand-holes at the ends of the cast-iron pipes on each side of the obstacle and joining these by lead-covered insulated cables of the full current-carrying capacity of the system. These cables can be bent round the obstacle and are in no way a weak point of the system.

After describing, in these general terms, the special features of the split tube system of laying underground conductors, the author proceeded to explain the method of laying them in the ordinary routine. For a three-wire system and a maximum of 2,000 lamps of three-quarter ampères a three-inch gas pipe may be used. Each insulating disc has three one-inch holes in the positions of the angles of an equilateral triangle. In adding fresh lengths of conductor three split tubes are first pinched at their ends and pushed into the ends of the three split tubes projecting from the last cast-iron pipe laid. Two insulators are next run along the split tube to a distance from either end of the tubes of one-fourth of their length. A fresh cast-iron pipe is now run along over the split tubes and their insulators, the latter fitting loosely in the pipes. The joint of the pipes is made with packing in the ordinary way. A new length is added in the same way. Man-holes must be placed at each corner of a street, and may be half a mile apart. The cast-iron pipes fit into side-holes in these boxes, and are fitted in with water-tight cement or packing. Wires are pulled through from man-hole to man-hole and may be soldered together across the man-hole. Finally holes are drilled and tapped in the cast-iron pipes beside those houses which require a supply of electricity. Two insulated wires, bared and flattened at their ends, are soldered to those split copper tubes which are of the right potentials, a one-inch gas pipe is screwed into the hole tapped in the main pipe, and the insulated wire is thus led into the house.

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4. *On an Electric Current Meter.* *By* Professor G. Forbes, *M.A., F.R.S. L. & E.*—See Reports, p. 564.

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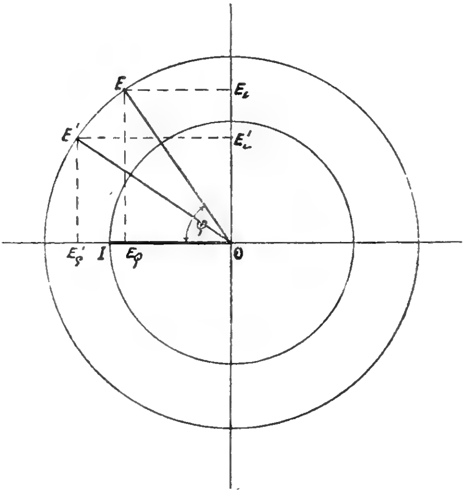
5. *On the Condition of Maximum Work obtainable from a given source of alternating Electromotive Force.* *By* Gisbert Kapp.

A circuit having a sensible self-induction L, and resistance r, receives current either from an alternate current dynamo direct or through a transformer, the E.M.F. impressed on the terminals of the circuit being supposed to vary according to a simple sine function, such as $e = \mathrm{E} \sin (a + \phi)$, where e is the E.M.F. at any moment, E is its maximum value, ϕ is the angle of lag, and $a = 2\pi nt$, n being the reciprocal of the periodic time, and t the time at which the electromotive force e is taken. Graphically this electromotive force can be represented by the projection of $\overline{\mathrm{OE}} = \mathrm{E}$

upon the vertical and the current $i = \mathrm{I} \sin a$ can be represented by the projection of $\overline{\mathrm{OI}} = \mathrm{I}$ upon the vertical. In the diagram the maximum electromotive force of self-induction is given by the line $\overline{\mathrm{OE}_\iota} = \mathrm{E}_\iota$, and the maximum electromotive force necessary to overcome the inert resistance of the circuit by the line $\overline{\mathrm{OE}_\rho} = \mathrm{E}_\rho$.



$$\mathrm{E}_\iota = 2\pi n \mathrm{LI}$$
$$\mathrm{E}_\rho = r\mathrm{I}$$
$$tg\phi = \frac{2\pi n \mathrm{L}}{r}$$

The work in time dt is $d\mathrm{W} = \frac{\mathrm{EI}}{2\pi n} \sin\ (a+\phi) \sin ada$, which integrated between the limits $a = o$ and $a = 2\pi$, and divided by the periodic time, gives the rate of working—

$$\mathrm{W} = \frac{\mathrm{EI}}{r} \cos\phi.$$

Let e and i represent the measured values of electromotive force and current; then we have also—

$$\mathrm{W} = ei \cos\phi.$$

In a continuous current system $\phi = o$, and the measured volt-ampère capacity of the plant is ei, all of which is available for doing work. In an alternate current system the available work is reduced in the ratio of 1 to $\cos\phi$; hence $\cos\phi$ might be called the plant efficiency.

To make the work a maximum for a given E, $\mathrm{I}\cos\phi$ must be a maximum. From diagram

$$\mathrm{E}_\iota = \mathrm{E}\sin\phi;$$

and since $\mathrm{E}_\iota = 2\pi n\mathrm{LI}$, $\mathrm{I} = \frac{\mathrm{E}\sin\phi}{2\pi n \mathrm{L}}$, and

$$\mathrm{I}\cos\phi = \frac{\mathrm{E}\sin\phi\cos\phi}{2\pi n\mathrm{L}},$$

which becomes a maximum, for $\phi = 45°$. In this case

$$\mathrm{E}_\rho = \mathrm{E}_\iota.$$

Maximum work is done in the circuit if the electromotive force of self-induction equals the electromotive force necessary to overcome the inert resistance.

In case the circuit contain a source of counter electromotive force, such for instance as a series wound, continuous current motor, with well-laminated field, excited to a low degree of magnetisation, the same reasoning applies. For the counter electromotive force is in this case proportional to the current, and therefore of the same character and period as the electromotive force necessary to overcome the inert resistance—

$$E\rho = (r + K)I,$$

where K is a coefficient depending on the constructive data of the machine, and on its speed, but not depending on its self-induction and periodic time. In a good motor r must be small as compared with K, and therefore the approximate condition to obtain maximum work is that the counter electromotive force developed in the armature should equal the electromotive force of self-induction. In this case the plant efficiency is about 71 per cent.

Motors as usually constructed, and running at moderate speed, do, however, not fulfil this condition, the electromotive force of self-induction being far too high. Improvements are necessary in the direction of reducing the self-induction, and at the same time increasing the counter electromotive force of these machines.

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6. *Distribution by Transformers and Alternate Current Machines.* *By* C. H. W. Biggs *and* W. H. Snell.

The authors noticed the frequency in industrial applications of science of results, which in the initial stages were indirect, becoming direct and of the greatest importance. The leading requirements of a general system of electrical distribution are well known, and may be considered under the heads of economy, safety, and availability. Considerations of economy require high potential in the mains, while safety requires a low potential at the point of use. The authors considered the advantages and disadvantages of the various systems in use, and concluded that in the immediate future the best prospect of economic and safe distribution was in the use of transformers, with constant current in the mains. When Gauland and Gibbs first introduced the system they used constant current, but could not overcome the practical difficulties of the case. Subsequently Messrs. Snell and Kent suggested a method of overcoming the difficulties, but found that the same device had previously been suggested by Elihu Thomson in America. This device utilises from ·5 to 1 per cent. of the current, and as far as experiments yet show with almost perfect regulation. Several other schemes of regulation have been devised, and the authors contended that, if the devices were as stated by the inventors, the method of distribution should revert back to the constant current, in preference at all points to the constant potential. The use of transformers, it was pointed out, would lead to a renewed use of alternate current machines, which would probably be in the future constructed on the lines indicated.

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7. *The Telemeter System.* *By* F. R. Upton.

The author explains that the 'Telemeter System,' invented by C. L. Clarke of New York, is a method by which the slow movement of a revolving hand of any indicating instrument may be reproduced by the movement of a similar hand at a distant place, using electricity to convey the impulse.

The primary hand moves until it makes electrical contact, thus sending an impulse. It is here that all previous methods have failed. This contact should be absolute and positive, for if it is not, the receiver will not work in unison. The contact could often be doubled by the jarring of the instrument, thus making the receiver jump twice.

Clarke has overcome this defect by so arranging his mechanism that the faintest contact in the primary instrument closes two platinum points in multiple arc with it, thus making a firm and positive contact, which is not disturbed by any jar on the primary contact. This gives the instruments a positive start for the series of

operations, instead of the faint contact which would be given, for example, by the light and slowly moving hand of a metallic thermometer.

The other trouble with previous methods was that the contact points would corrode, and, in consequence of such corrosion, the instrument would fail to send impulses. Corrosion of the contacts is due to breaking the circuit slowly on a small surface. This is entirely remedied by breaking the circuit elsewhere than the primary contact, using a quick motion, and also by giving this breaking contact large surface and making it firm.

The instrument, as applied to a thermometer, is made as follows:—From the free end of the light spiral of a metallic thermometer fixed at the other end, an arm is attached the end of which moves over an arc of a circle when the temperature varies. This end carries on either side of its extremity platinum contacts which, when the thermometer is at rest, lie between two other platinum points carried on radial arms. Any variation in temperature brings a point on the thermometer arm in contact with one of these points and thus gives the initial start to the series of operations without opposing any friction to the free motion of the instrument.

The first result is the closing of a short circuit round the initial point of contact, so that no current flows through it. Then the magnets which operate one set of pawls come into play. The two contact points are attached to a toothed wheel in which the pawls play, and these pawls are so arranged that they drive the wheel whenever moved by their magnets: thus the primary contact is broken.

In the receiver there is a similar toothed wheel bearing the hand of the indicating instrument, and actuated at the same moment as the transmitter. The primary contacts are so arranged that the contact is made for each degree of temperature to be indicated. This series of operations leaves the instruments closed, and the pawls home in the toothed wheel. To break the circuit another wire and separate set of contacts are employed. These are arranged on the arms carrying the pawls, and so adjusted that no contact is made until after the toothed wheel has moved a degree, when a circuit is closed and a magnet attracts an armature attached to a pendulum. This pendulum after starting breaks the circuit of the magnets which hold the pawls down, as well as of the short-circuiting device. As the pendulum takes an appreciable time to vibrate, this allows all the magnets to drop back, and breaks all circuits, leaving the primary contacts in the same relation as at first.

The many details of the instruments are carefully worked out. All the contacts are rubbing contacts, thus avoiding danger from dirt, and they are made with springs so as not to be affected by jar.

The receiving instruments can be made recorders also by simple devices. Thus, having only a most delicate pressure in the primary instrument, a distinct ink record may be made in the receiver, even though the paper be rough and soft.

The method is applicable to steam-gauges, water-level indicators, clocks, barometers, &c., in fact to any measuring instrument where a moving hand can be employed.

TUESDAY, SEPTEMBER 6.

The following Report and Papers were read:—

1. *Report of the Committee on the Endurance of Metals under repeated and varying Stresses.*—See Reports, p. 424.

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2. *On the Resistance of Stone to Crushing, as affected by the material on which it is bedded. By* Professor W. C. UNWIN, *F.R.S.*

Twenty years ago, it was common in experiments on crushing to bed the test specimens of rigid materials like stone on lead plates, with an idea of securing uniform distribution of pressure on the faces at which the crushing pressure is applied. The author has long had the opinion that to support blocks for crushing

on a plastic support is wrong in principle. Hence in experiments on the crushing of stone, and of Portland cement and concrete, he has adopted the plan of preparing the faces on which the crushing pressure acts, with a thin layer of plaster. This can easily be worked to smooth and parallel surfaces, used to receive the iron plates of the crushing shackles directly, if necessary; but the author generally interposes a sheet of millboard, which is a very hard and only slightly compressible material. It seemed desirable to try what was the difference of the crushing strength of blocks supported in these two ways. Two series of 4 in. cubes of Portland stone and Yorkshire grit were obtained of very uniform quality. The results of the tests are given below. The author has been surprised at the very great reduction of strength which occurs when a thin plate of plastic material like lead is used on the faces to which the crushing pressure is applied. It will be seen that the crushing pressure of blocks between lead plates is in one case only three-fifths, and in another only three-sevenths of that of blocks prepared with plaster and crushed between millboard. One block was cemented carefully between two rigid iron plates with parallel surfaces, and this carried a little more, but only a little more, load than the block prepared with plaster and crushed between loose millboards. An examination of the mode of fracture of the blocks shows why the lead has so dangerous an effect on the strength. The blocks crushed between millboards sheared approximately at 45° in the way well understood, forming regular pyramids; but the blocks crushed between lead broke up into a number of vertical prisms with nearly vertical faces. The lead, flowing under the crushing pressure, produced by friction a tension in the block at right angles to the crushing pressure, tearing the block in pieces and completely altering the angle of fracture. The pressure of fluidity of lead is known to be from $1\frac{1}{2}$ to 3 tons per square inch, and these pressures were exceeded in the crushing experiments.

The result seems important, because it is still a common practice to use lead, or deal, or some other plastic or compressible material, in crushing experiments, and it is not generally known that this has the effect of diminishing the crushing resistance.

Crushing of Stone Blocks, 4 in. cubes (approximately).

Description of Stone	Crushing Load in tons	Stress in tons per sq. ft.	
PORTLAND—			
535	57·665	516·384	Between two millboards on each face.
536	52·600	469·872	One plate of lead on each face.
538	45·65	408·8	One plate of lead on each face $\frac{1}{8}''$ smaller than face all round.
537	33·50	299·952	Three plates of lead on each face.
YORKSHIRE GRIT—			
539	79·72	712·080	Between two millboards on each face.
542	80·05	716·86	Cemented between two strong iron plates with plaster of Paris.
540	56·20	504·432	One lead plate on each face.
541	35·90	322·272	Three plates of lead on each face.

The lead plates were 0·085 in. thick.

3. *Expansive Working in Direct-acting Pumping Engines.* *By* HENRY DAVEY, *M.Inst.C.E.*

In the Report of the Swansea meeting of the British Association is printed a paper by the author on the above subject, describing a method by means of which expansive working is secured without the use of a flywheel.

The present paper describes a more recent invention of the author's by means of which a far greater degree of expansion is made possible.

When an engine has heavy reciprocating parts, such as long pump rods or loaded plungers, expansive working is possible because of the inertia at the beginning and the momentum towards the end of the stroke, expressed by the formula $\frac{WV^2}{2g}$. By this method for a considerable degree of expansion a very high velocity must be given to the mass when the weight is small. In engines which have not long pump-rods it is not always convenient to provide weights sufficiently heavy to enable a high degree of expansion to be employed. The mechanism which the author proceeds to describe practically equates the engine power and the pump resistance by causing the decreasing pressures of the expanding steam on the piston of the engine to bring a nearly constant force to bear on the pump throughout the stroke.

In figure 1 let the pump resistance be represented by the parallelogram *a, b, c, d,* and the engine power diagram by the figure *c, e, f, g, d,* and supposing the parts of the engine to have no weight, then means are required by which the piston of the engine may move with varying velocities relative to that of the pump piston, exceeding the mean velocity by the ordinates 1, 2, 3, and falling short of that velocity by the ordinates 4, 5, 6.

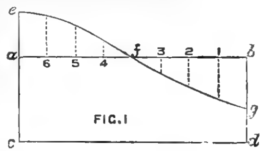
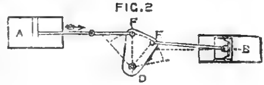


FIG. 1

Let A (figure 2) be the engine, and B the pump piston, and C a triangular frame turning on the fulcrum D. The pump piston is attached to the frame at the point E by means of a vibrating connecting rod, and the engine piston to the point F by means of a similar rod. Whilst the engine is making its stroke in the direction of the arrow the pump piston is decreasing in velocity relative to that of the engine piston, the ratio being determined by the relative positions of E and F.

FIG. 2


In applying this mechanism to pumping engines it is first necessary to determine the ratio of expansion to be employed, and then to see how nearly the force and resistance can be equated.

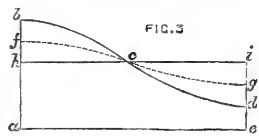


FIG. 3

Let *a, b, c, d, e* (fig. 3) be the combined diagrams of a compound engine working with the given ratio of expansion, *a, f, g, e,* the diagram of effects of the varying velocities of the engine and pump pistons, and *a, h, i, e,* the pump-resistance diagram. Then acceleration of velocity takes place from *h, c,* and knowing the weight of the moving parts the acceleration may be calculated. It will at once be seen that the mechanical advantage obtained by this mechanism greatly reduces the acceleration for a given mass.

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4. *Reinforcing Electrical Contacts so as to increase their Reliability, with Example of Application to Reeling Silk from the Cocoon. By* E. W. Serrell, Jun.

The object of the paper is to explain a method of securing a good electric contact under circumstances in which ordinary solid or mercury contacts will not work.

The method consists in the use of a sucking coil or small electro-magnet, placed near the contact and traversed by the whole or a part of the current when the circuit is closed. When the contacts touch, no matter how lightly or imperfectly, the magnet or coil is excited, and acts on an armature in such manner as to cause the parts of the contact to be drawn more firmly together and to scrape over one another so as to be cleaned by a mechanical action produced by the current itself every time that contact is made. By this method all the difficulties commonly

experienced in the use of electric contacts may be overcome. If the parts are made to touch even in the slightest degree a thoroughly good contact is instantly secured.

The method is applicable to signalling apparatus and many other purposes, and is already used with success by the inventor in automatic machinery for reeling silk from the cocoon. By its use contacts have worked reliably for very long periods under circumstances which would give rise to insuperable difficulties without it.

Its application to automatic machinery for reeling silk from the cocoon was explained. This machinery has created a new industry, all silk having hitherto been reeled by hand.

The use of electrical appliances for reeling silk is greatly facilitated by the employment of this device and is leading to important results; and the inventor considers that, as by this means a perfectly reliable contact is easily obtained, the use of electricity for controlling textile and other machinery may be very greatly and advantageously extended, especially in all cases in which light contacts must be used.

5. *A new Form of Secondary Battery.* *By* KILLINGWORTH HEDGES.

This battery is of the Planté type and designed to obtain the maximum of surface for the peroxide plate, while the total weight is much reduced and the available electro-motive force is increased by using a strip of zinc for the positive plate instead of lead as in all modifications of the Planté form. The peroxide plate is constructed on M. Bailly's method, the main conductor ramifying throughout the mass of the plate. A basket work of lead wool is tightly pressed into the space left between a porous pot or plate and the outside receptacle of the battery, this diaphragm offering little resistance to the passage of the current as it is made of compressed sand, and it prevents any possibility of short circuit with the positive or reduced electrode. The current is led from the zinc plate by causing it and the connecting wire to dip in mercury; this plan helps to keep up the amalgamation. The lead-zinc battery is not new, but this is the first in which ordinary zinc has been employed instead of lead or copper coated with zinc electrolytically. The action is as follows:—the zinc is attacked by the sulphuric acid in the presence of the peroxide of lead, the latter acting as a perfect depolariser; the reaction is much more energetic than in a lead-lead couple, the available EMF being 2·5 volts. In discharging, the zinc plate dissolves in the dilute acid, and the sulphate of zinc formed is decomposed on re-charging, metallic zinc being deposited on the zinc plate. Thus the zinc is never consumed but is only dissolved and re-deposited. The external cells are made of very thin celluloid. A basket containing six of these cells, each of 60 ampère-hour capacity, which will maintain six four-candle lamps for over eight hours, weighs under one hundredweight. The lamps were shown at work.[1]

6. *Underground Electrical Work in America.* *By* F. BREWER.

7. *Improvements in Lifeboats.* *By* J. T. MORRIS.

8. *Link Motion for Steam Engines.* *By* J. M. MCCULLOCH.

9. *On the Communication of Motion between bodies moving at different Velocities.* *By* J. WALTER PEARSE.

This combination, devised by M. R. Suyers, of Brussels, is described by him as the 'infinitesimal division of a mass into elastic elements and their dynamical in-

[1] For illustration see *Electrical Review*, May 24, 1887.

tegration.' Its effect is, without shock or breakage, to set in motion a body at rest by the instantaneous action of another moving at a high velocity or to arrest any mass, whatever be its velocity. The principle is carried out by dividing the mass into flexible elements, which take the form of metallic fibres resembling a brush. On impact each fibre acts independently of the rest, the mass being negligeable, but the dynamic effect exerted by the sum of the fibres is considerable. The flexibility of the fibres must be in direct ratio to the speed of the moving body or the difference in velocity of two moving bodies. The most obvious applications are taking up the recoil of a cannon, arresting a mine cage on the rope breaking, preventing a motor from 'running away' on the load being suddenly taken off, or the prevention of shock on the load being suddenly increased, and the setting of a signal to danger by a train so as to protect it, or the automatic arrest of a train by the signal.

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10. *The Tangye Gas Hammer.*[1] *By* Dugald Clerk.

The paper gives details as to the working, &c., of a gas hammer which is the invention of Mr. Jas. Robson, and was exhibited at the Inventions Exhibition in 1885. Since then it has been continually in action at Cornwall Works, Birmingham; it has been much simplified and improved in its details, and is as reliable and controllable as any steam hammer.

It resembles a steam hammer in design, and contains a piston, a piston rod connecting with the top containing the hammer, and an anvil block.

The cylinder, however, is longer, and a space is left above the hammer piston to contain the necessary charge of gas and air. A second piston is arranged to fill and discharge the explosion space.

The impulse for the blow is given to the hammer piston by the explosion above it, and the return of the hammer to its highest position is effected by means of a volute spring; when out of action, therefore, the hammer always remains up.

The charging piston is actuated by a hand lever, and is an easy fit in the cylinder. When the hand lever is moved in one direction, the charging piston moves downwards towards the hammer piston, and the products of a previous explosion pass through automatic lift valves in it to the upper side. On the return movement the charging piston rises, and the automatic valves, closing, cause the spent gases to be discharged at a port in the top of the cylinder, while a fresh charge of gas and air is drawn in between the pistons; at the upper extremity of the stroke the charging piston covers the exhaust port, and then an igniting valve opens to effect the explosion; the hammer descends, strikes its blow, and when the hand lever is moved to transfer the exhaust gases again, the spring returns it to its upper position. This is the complete cycle of action.

The hand lever actuating the second or charging piston is arranged to move precisely like the hand lever commonly used in steam hammers for controlling the slide valve; the similar movement produces precisely similar results, and the effort required is no greater. The blows can easily be given at the rate of 120 per minute.

To reduce the force of the blow the hand or foot is moved through a smaller range and a smaller volume of explosive mixture drawn in, and therefore a more feeble explosion obtained. For very light blows a relief valve is opened to discharge a portion of the pressure.

The energy of the blow may be determined in two ways—first by taking an indicator diagram, and second by measuring the velocity acquired by the hammer before it strikes the forging.

Diagrams so taken proved the maximum pressure to be 56 lbs. per square inch above the atmosphere, and an average of 22·5 lbs. during the whole downward movement of the hammer piston. As the cylinder is 7 in. in diameter and the fall of the hammer 6 in., this amounts to 433 foot-pounds, which, after adding on the energy due to the fall of the hammer and deducting that due to the resistance of the springs, becomes 406 foot-pounds, or 3·62 cwt. falling through one foot.

[1] Published *in extenso* in *Industries*, October 14, 1887, p. 414.

This is the case when the hammer cylinder is cold; when hot the average driving pressure falls to 20 lbs. per square inch and the blow to 3·19 cwt., falling through a foot, or 358 foot-pounds. The gas used is 1 cubic foot for 94 of the latter blows.

Birmingham gas with which these experiments were made costs 2*s.* 6*d.* per 1,000 cubic feet or 33 cubic feet for one penny, and $33 \times 94 = 3{,}102$ blows are thus obtained at the cost of one penny. This is an exceedingly economical and satisfactory result.

The paper concludes with a statement of the several purposes to which this hammer can with advantage be applied.

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11. *On the British Association Standard Screw Gauge.* *By* W. H. PREECE, *F.R.S.*

Owing to the large number of telegraph instruments made by different manufacturers the number of screws of different forms and sizes in use was very great, and this was found to be a great disadvantage and a great source of expense. When the Post Office commenced to manufacture its own apparatus it was decided to make all parts to template, so as to be interchangeable; and it was also decided to adopt some standard for screws. The standard recommended by the Committee appointed by the British Association is now being introduced in all instruments and apparatus manufactured by and for the Post Office Department, a circular to that effect having been issued to all firms manufacturing for the G.P.O.

A set of standard taps and plates was exhibited.

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12. *A Fire-damp Indicator.* *By* J. WILSON SWAN.

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13. *On an improved Railway Reading Lamp.* *By* W. H. PREECE, *F.R.S.*

Section H.—ANTHROPOLOGY.

President of the Section—Professor A. H. Sayce, M.A.

THURSDAY, SEPTEMBER 1.

The President delivered the following Address:—

Surprise has sometimes been expressed that anthropology, the science of man, should have been the last of the sciences to come into being. But the fact is not so strange as it seems at first sight to be. Science originated in curiosity, and the curiosity of primitive man, like the curiosity of a child, was first exercised upon the objects around him. The fact that we are separate from the world about us, and that the world about us is our own creation, is a conviction which grows but slowly in the mind either of the individual or of the race in general. The child says, 'Charley likes this,' before he learns to say, '*I* like this,' and in most languages the objective case of the personal pronoun exhibits earlier forms than the nominative.

Moreover, it is only through the relations that exist between mankind and external nature that we can arrive at anything like a scientific knowledge of man. Science, it must be remembered, implies the discovery of general laws, and general laws are only possible if we deal, not with the single individual, but with individuals when grouped together in races, tribes, or communities. We can never take a photograph of the mind of an individual, but we can come to know the principles that govern the actions of bodies of men, and can employ the inductive method of science to discover the physical and moral characteristics of tribes and races. It is through the form of the skull, the nature of the language, the manners and customs, or the religious ideas of a people that we can gain a true conception of their history and character. The thinker who wishes to carry out the precept of the Delphian oracle and to 'know himself' must study himself as reflected in the community to which he belongs. The sum of the sciences which deal with the relations of the community to the external world will constitute the science of anthropology.

The field occupied by the science is a vast one, and the several workers in it must be content to cultivate portions of it only. The age of 'admirable Crichtons' is past; it would be impossible for a single student to cover with equal success the whole domain of anthropology. All that he can hope to do is to share the labour with others, and to concentrate his energies on but one or two departments in the wide field of research. A day may come when the work we have to perform will be accomplished, and our successors will reap the harvest that we have sown. But meanwhile we must each keep to our own special line of investigation, asking only that others whose studies have lain in a different direction shall help us with the results they have obtained.

I shall therefore make no apology for confining myself on the present occasion to those branches of anthropological study about which I know most. It is more particularly to the study of language, and the evidence we may derive from it as to the history and development of mankind, that I wish to direct your attention. It is in language that the thoughts and feelings of man are mirrored and embodied; it is through language that we learn the little we know about what is passing in the minds of others. Language is not only a means of intercommunication, it is

also a record of the ideas and beliefs, the emotions and the hopes of the past generations of the world. In spoken language, accordingly, we may discover the fossilised records of early humanity, as well as the reflection of the thoughts that move the society of to-day. What fossils are to the geologist words are to the comparative philologist.

But we must be careful not to press the testimony of language beyond its legitimate limits. Language is essentially a social product, the creation of a community of men living together and moved by the same wants and desires. It is one of the chief bonds that bind a community together, and its existence and development depend upon the community to which it belongs. If the community is changed by conquest or intermarriage or any other cause the language of the community changes too. The individual who quits one community for another has at the same time to shift his language. The Frenchman who naturalises himself in England must acquire English; the negro who is born in the United States must adopt the language that is spoken there.

Language is thus a characteristic of a community, and not of an individual. The neglect of this fact has introduced untold mischief not only into philology, but into ethnology as well. Race and language have been confused together, and the fact that a man speaks a particular language has too often been assumed, in spite of daily experience, to prove that he belongs to a particular race. When scholars had discovered that the Sanskrit of India belonged to the same linguistic family as the European languages, they jumped to the conclusion that the dark-skinned Hindu and the light-haired Scandinavian must also belong to one and the same race. Time after time have I taken up books which sought to determine the racial affinities of savage or barbarous tribes by means of their language. Language and race, in short, have been used as synonymous terms.

The fallacy is still so common, still so frequently peeps out where we should least expect it, that I think it is hardly superfluous, even now, to draw attention to it. And yet we have only to look around us to see how contrary it is to all the facts of experience. We Englishmen are bound together by a common language, but the historian and the craniologist will alike tell us that the blood that runs in our veins is derived from a very various ancestry. Kelt and Teuton, Scandinavian and Roman have struggled together for the mastery in our island since it first came within the horizon of history, and in the remoter days of which history and tradition are silent archæology assures us that there were yet other races who fought and mingled together. The Jews have wandered through the world adopting the languages of the peoples among whom they have settled, and in Transylvania they even look upon an old form of Spanish as their sacred tongue. The Cornishman now speaks English; is he on that account less of a Kelt than the Welshman or the Breton?

Language, however, is not wholly without value to the ethnologist. Though a common language is not a test of race, it is a test of social contact. And social contact may mean—indeed very generally does mean—a certain amount of intermarriage as well. The penal laws passed against the Welsh in the fifteenth century were not sufficient to prevent marriages now and then between the Welsh and the English, and in spite of the social ostracism of the negro in the Northern States of America intermarriages have taken place there between the black and the white population. But in the case of such intermarrying the racial traits of one member only of the union are, as a general rule, preserved. The physical and moral type of the stronger parent prevails in the end, though it is often not easy to tell beforehand on which side the strength will lie. Sometimes, indeed, the physical and moral characters are not inherited together, the child following one of his parents in physical type while he inherits his moral and intellectual qualities from the other. But even in such cases the types preserve a wonderful fixity, and testify to the difficulty of changing what we call the characteristics of race.

Herein lies one of the most obvious differences between race and language, a difference which is of itself sufficient to show how impossible it must be to argue from the one to the other. While the characteristics of race seem almost indelible, language is as fluctuating and variable as the waves of the sea. It is perpetually

changing in the mouths of its speakers; nay, the individual can even forget the language of his childhood and acquire another which has not the remotest connection with it. A man cannot rid himself of the characteristics of race, but his language is like his clothing which he can strip off and change almost at will.

It seems to me that this is a fact of which only one explanation is possible. The distinctions of race must be older than the distinctions of language. On the monuments of Egypt, more than four thousand years ago, the Libyans are represented with the same fair European complexion as that of the modern Kabyles, and the painted tomb of Rekh-mâ-ra, a Theban prince who lived in the sixteenth century before our era, portrays the black-skinned negro, the olive-coloured Syrian, and the red-skinned Egyptian with all the physical peculiarities that distinguish their descendants to-day. The Egyptian language has ceased to be spoken even in its latest Coptic form, but the wooden figure of the 'Sheikh-el-beled' in the Bulaq Museum, carved 6,000 years ago, reproduces the features of many a *fellah* in the modern villages of the Nile. Within the limits of history racial characteristics have undergone no change.

I see, therefore, no escape from the conclusion that the chief distinctions of race were established long before man acquired language. If the statement made by M. de Mortillet is true, that the absence of the mental tubercle, or bony excrescence in which the tongue is inserted, in a skull of the Neanderthal type found at La Naulette, indicates an absence of the faculty of speech, one race at least of palæolithic man would have existed in Europe before it had as yet invented an articulate language. Indeed, it is difficult to believe that man has known how to speak for any very great length of time. On the one hand, it is true, languages may remain fixed and almost stationary for a long series of generations. Of this the Semitic languages afford a conspicuous example. Not only the very words, but even the very forms of grammar are still used by the Bedouin of Central Arabia that were employed by the Semitic Babylonians on their monuments five thousand years ago. At that early date the Semitic family of speech already existed with all its peculiarities, which have survived with but little alteration up to the present day. And when it is remembered that Old Egyptian, which comes before us as a literary and decaying language a thousand years earlier, was probably a sister of the parent Semitic speech, the period to which we must assign the formation and development of the latter cannot fall much short of ten thousand years before the Christian era. But on the other hand there is no language which does not bear upon its face the marks of its origin. We can still trace through the thin disguise of subsequent modifications and growth the elements, both lexical and grammatical, out of which language must have arisen. The Bushman dialects still preserve the inarticulate clicks which preceded articulate sounds in expressing ideas; behind the roots which the philologist discovers in allied groups of words lie, plainly visible, the imitations of natural sounds, or the instinctive utterances of human emotion; while the grammar of languages like Eskimaux or the Aztec of Mexico carries us back to the first mechanism for conveying the meaning of one speaker to another. The beginnings of articulate language are still too transparent to allow us to refer them to a very remote era. I once calculated that from thirty to forty thousand years is the utmost limit that we can allow to man as a speaking animal. In fact, the evidence that he is a drawing animal, derived from the pictured bones and horns of the palæolithic age, mounts back to a much earlier epoch than the evidence that he is a speaking animal.

Mr. Horatio Hale has lately started a very ingenious theory to account, not indeed for the origin of language in general, but for the origin of that vast number of apparently unallied families of speech which have existed in the world. He has come across examples of children who have invented and used languages of their own, refusing at the same time to speak the language they heard around them. As the children belonged to civilised communities the languages they invented did not spread beyond themselves, and after a time were forgotten by their own inventors. In an uncivilised community, however, it is quite conceivable that such a language might continue to be used by the children after they had begun to grow up and be communicated by them to their descendants. In this case a wholly new language would be started, which would have no affinities with any other, and after splitting into

dialects would become the parent of numerous derived tongues. I must confess that the evidence brought forward by Mr. Hale in support of his theory is not quite convincing to me. It has yet to be proved that the words used by the children to whom he refers were not echoes of the words used by their elders. If they were, a language that originated in them would show more signs of lexical affinity to the older language than is the case with one family of speech when compared with another. On the other hand, the theory would tend to throw light on the curious fact that the morphological divisions of language are also geographical.

By the morphology of a language I mean its structure, that is to say, the mode in which the relations of grammar are expressed in a sentence, and the order in which they occur. These vary considerably, the chief variations being represented by the polysynthetic languages of America, the isolating languages of Eastern Asia, the postfixal languages of Central Asia, the prefixal languages of Africa, and the inflectional languages of Europe and Western Asia. Now it will be observed that each of these classes of language is associated with a particular part of the globe, the isolating languages, for example, being practically confined to Eastern Asia, and the polysynthetic languages to America. Within each class there are numerous families of speech between which no relationship can be discovered beyond that of a common structure; they agree morphologically, but their grammar and lexicon show no signs of connection. If we adopt Mr. Hale's theory we might suppose that the genealogically distinct families of speech grew up in the way he describes, while their morphological agreement would be accounted for by the inherited tendency of the children to run their thinking into a particular mould. The words and contrivances of grammar would be new, the mental framework in which they were set would be an inheritance from former generations.

I have spoken of the inflectional languages as belonging to Europe and Western Asia. This is true if we give a somewhat wide extension to the term inflectional, and make it include not only the Indo-European group, but the Georgian and Semitic groups as well. But, strictly speaking, the Indo-European, or Aryan, languages have a structure of their own, which differs very markedly from that of either the Georgian or the Semitic families. The Semitic mode of expressing the relations of grammar by changing the vowels within a framework of consonants differs as much from the Aryan mode of expressing them by means of suffixes as does the Semitic partiality for words of three consonants from the Indo-European carelessness about the number of syllables in a word. Though it is quite true that the Semitic languages at times approach the Indo-European by using suffixes to denote the forms of grammar, while at other times the Indo-European languages may substitute internal vowel change for external flection, nevertheless, in general, the kind of flection employed by the two families of speech is of a totally different character.

This difference of structure, coupled with a complete difference in phonology, grammar, and lexion, has always seemed to me to negative the attempts that have been made to connect the Aryan and Semitic families of language together. The attempts have usually been based on the old confusion between language and race; both Aryans and Semites belong to the white race; therefore it was assumed their languages must be akin. As long as it was generally agreed that the primitive home of the Aryan languages was, like that of the Semitic languages, the western part of Asia, the confusion was excusable. If the earliest seats of the speakers of each were in geographical proximity, there was some reason for believing that languages which were alike spoken by members of the white race, and were alike classed as inflectional, would, when properly questioned, show signs of a common origin.

But that general agreement no longer exists. While the Asiatic origin of the Semitic languages is beyond dispute, scholars have of late years been coming more and more to the conclusion that Europe was the cradle of the Aryan tongues. Their European origin was first advocated by our countryman Dr. Latham, and was subsequently defended by the eminent comparative philologist Dr. Benfey; but it is only within the last half-dozen years that the theory has won its way to scientific recognition. Different lines of research have been converging towards the

same result, and indicating north-eastern Europe as the starting-point of the Indo-European languages, while the evidences invoked in favour of their Asiatic origin have one and all broken down.

These evidences chiefly rested on the supposed superiority of Sanskrit over the other Indo-European languages as a representative of the parent-speech from which they were all descended. The grammar and phonology of Sanskrit were imagined to be more archaic, more faithful to the primitive pattern than those of its sister-tongues. It was argued that this implied a less amount of migration and change on the part of its speakers, a nearer residence, in fact, to the region where the parent-speech had once been spoken. As a comparison of the words denoting certain objects in the Indo-European languages showed that this region must have had a cold climate, it was placed on the slopes of the Hindu-Kush or at the sources of the Oxus and Jaxartes.

But we now know that instead of being the most faithful representative of the parent-speech, Sanskrit is in many respects far less so than are its sister-languages of Europe. Its vocabulary, for instance, has been thrown into confusion by the coalescence of the three primitive vowel sounds ă, ĕ, ŏ into the single monotonous *ă*, a corruption which is paralleled by the coalescence of so many vowels in modern cultivated English in the so-called 'neutral' *e*. Greek, or even the Lithuanian, which may still be heard to-day from the lips of unlettered peasants, has preserved more faithfully than the Sanskrit of India the features of the parent Aryan. If the faithfulness of the record is any proof of the geographical proximity of one of the Indo-European languages to their common mother, it is in the neighbourhood of Lithuania, rather than in the neighbourhood of India, that we ought to look for traces of the first home of the Aryan family.

But the theory of the Asiatic origin of the Indo-European family has not only been deprived of its main support by the dethronement of Sanskrit, and the transfer of its primacy to the languages of Europe, what Professor Max Müller has termed 'linguistic palæontology' has further assisted in overthrowing the crumbling edifice. When we find words of similar phonetic form and similar meaning in both the Asiatic and the European branches of the Aryan family—words, too, which it can be shown have not been borrowed by one Indo-European language from another—we are justified in concluding that the objects or phenomena denoted by them were already known to the speakers of the parent language. When we find, for instance, that the birch is known by the same name in both Sanskrit and Teutonic, we may infer that it was a tree with which the speakers of the mother tongue of Sanskrit and Teutonic were acquainted, and that consequently they must have lived in a cold climate.

Four years ago a valuable contribution to the linguistic palæontology of the Aryan languages was made by Professor Otto Schrader. For the first time the question was approached from the present level of comparative philology, and all words were excluded from comparison which did not satisfy the requirements of phonetic law. The results were sadly disquieting to the believers in that idyllic picture of primitive Aryan life to which we had so long been accustomed. Professor Schrader proved that the speakers of the parent Aryan language must not only have lived in a cold climate—a fact which was known already—but that they must have lived in the stone age, with the skins of wild beasts only to protect them from the rigours of the winter, and nothing better than stone weapons with which to ward off the attacks of savage animals. Their general culture was on a level with their general surroundings. It was little better than that of the Fuegian before he came into contact with European missionaries. The minuteness with which the varying degrees of family relationship were named, instead of indicating an advanced social life, as was formerly imagined, really indicated the direct contrary. The primitive Aryan was indeed acquainted with fire; he could even sew his skins together by means of needles of bone; and possibly could spin a little with the help of rude spindle-whorls; but beyond this his knowledge of the arts does not seem to have extended. If he made use of gold or meteoric iron, it was only of the unwrought pieces which he picked up from the ground and employed as ornaments; of the working of metals he was entirely ignorant. But he already practised a kind of

rude agriculture, though the art of grinding corn was as yet unknown, and crushed spelt was eaten instead of bread; while the community to which he belonged was essentially that of pastoral nomads, who changed from season to season the miserable beehive huts of wattled mud in which they lived. They could count at least as far as a hundred, and believed in a multitude of ghosts and goblins, making offerings to the dead, and seeing in the bright sky a potent deity.

In calling the speaker of the Aryan parent speech the primitive Aryan I must not be supposed to be prejudging the question as to the particular race to which he belonged. This is a question which has recently been handled with great ability by an Austrian anthropologist—Dr. Karl Penka. In a remarkable book, published at the end of last year, he endeavours to substantiate the hypothesis advanced in an earlier work, and to show that the first speakers of the Aryan languages were the fair-haired, blue-eyed, light-complexioned dolichocephalic race, which is still found in its greatest purity in Scandinavia; that it was this race which in the neolithic period spread southwards, imposing its yoke upon subject populations, like the Norsemen and Normans of later days, and carrying with it the dialects, which afterwards developed into the Aryan languages; and that, finally, it was the same race which in the remote days of the palæolithic age inhabited western and central Europe, where it has left its remains in the typical skulls of Cannstatt and Engis. Dr. Penka would ascribe to its long residence in the semi-arctic climate of palæolithic Europe the permanent blanching of its skin and hair—a form of albinoism which Dr. Poesche in 1878 endeavoured to explain by the climatic conditions of the Rokitno marshes in Russia, where he placed the cradle of the white Aryan race.

It cannot be denied that all the probabilities are at present on Dr. Penka's side, so far as his main contention is concerned. Without denying that the speakers of the Aryan parent speech may have already included slaves or wives of alien race, it is probable that the majority of them were of one blood. They formed a single community, nomad it is true, and therefore less likely to mix with foreigners, but still sufficiently a single community to speak a language the several dialects of which were so alike as to be mutually intelligible. In the social condition in which the speakers were, and in an age when the waste lands of the world were still extensive, the greater part of such a community must necessarily, we should think, have belonged to the same race. The evidences of language, moreover, as we have seen, point to a cold and northerly climate as the original seat of the community; and since they further inform us that the beech was known to it, we may conclude that this climate lay westward of Königsberg and Russia. Penka has striven to show that the animals whose bones or shells are found in the Scandinavian kitchen-middens are just those whose names are common to the Indo-European languages, or at all events the European section of the latter. Now, the skulls disinterred from the prehistoric burial-places of Denmark and the southern districts of Sweden and Norway are, for the most part, identical with the skulls still characteristic of the Scandinavian population where they accompany a fair skin and light hair and eyes. By combining these two facts we arrive at the conclusion that the fair Scandinavian race is the modern descendant of the race which spoke the parent language of the primitive Aryan community, and left traces of itself in the Scandinavian kitchen-middens. The conclusion is supported by the testimony of history. On the one hand, we have the testimony of classical writers that the Aryan-speaking Kelts of the Christian era were not the dark small-limbed population which now occupies the larger part of France, but men of large stature, with the blue eyes and fair hair of their Teutonic brethren; while the ideal specimens of humanity conceived of by the aristocratic art of Italy and Greece were the golden-haired Apollo and the blue-eyed Athênê. On the other hand, it was from Scandinavia that in later times other bands of warriors poured forth, who made their way into the countries of the Mediterranean, and even Asia, and established themselves as conquering aristocracies in the midst of subject populations. The Kelts succeeded in reaching Asia Minor, the Scando-German hordes overthrew the Roman empire, the Northmen established themselves from Russia on the east to Iceland and Greenland on the west, and the Normans made Sicily their own long before the days of the

German Frederick. The only point in which the later historical irruptions of the Scandinavian peoples differed from their prehistoric ones was, that while the later irruptions were made by sea, the older were made by land. The sail was unknown to the tribes of the north until the age of their intercourse with the Romans, from whom they borrowed both the conception and the name of the *sagulum*, or 'sail.' The course of their migrations must have followed the valleys of the great rivers.

If southern Scandinavia is thus to be regarded as the original home of the Aryan languages, and the race which first spoke those languages, and which we may therefore call Aryan, is to be identified with the Scandinavian type, it follows that the further south and east we advance from this primary starting-point the less pure will the type become. It will be in the neighbourhood of that starting-point and in northern Europe that we shall expect to find the largest number of undiluted Aryan languages and the purest examples of the Aryan breed. In Greece and Armenia, in Persia and India we must look for mixture and decay. And such indeed is the fact. Mr. Wharton has found, by a careful analysis of the Greek lexicon, that out of 2,740 primary words only 1,580 can be referred with any probability to an Indo-European origin, while the prevailing racial type in ancient as in modern Greece was distinctly non-Aryan. Indeed, I am inclined to believe that the culture revealed by the excavations at Mykênæ, Tiryns, and on other prehistoric Greek sites belonged not to a Hellenic but to a pre-Hellenic population, and that the Aryan Greeks first made their appearance in Hellas at the epoch of what later tradition called the Dorian immigration. It was to the north that Greek legends pointed as the primæval home of the Hellenic race and civilisation, and Dôdôna ever continued to be revered as the oldest sanctuary of the Hellenic world. In India it is notorious that the Aryan-speaking Hindus entered the country from the north-west, and failed to spread far into the burning plains of the south. The date of their invasion is uncertain, but for myself I have grave doubts whether it was earlier than the eighth or even the seventh century B.C. At all events it was not until after the seventh century B.C., as we now know from the express testimony of the cuneiform inscriptions of Van, that the Aryan-speaking Armenians entered the land which now bears their name, and recent philological researches have confirmed the assertion of Greek writers that the Armenians were a colony of the Phrygians who had themselves emigrated from Thrace. Up to the closing days of the Assyrian empire the monuments make it clear that no Aryans had as yet settled between the Kurdish ranges on the east and the Halys on the west.

But while the extension into Asia of what I will now, following Penka's example, call the Aryan race, seems to be referred to a comparatively recent period, there is a curious fact which goes to show that the same, or a closely allied, race once spread along the northern coast of Africa. On Egyptian monuments, which date back to the sixteenth century before our era, the Libyan tribes of this district are described and depicted as white. Their descendants are still to be found in the mountainous parts of the coast, those of Algeria being commonly known under the name of Kabyles. I saw a good deal of them last winter, and must confess to being greatly struck by their appearance. I had known, of course, that they belonged to the white race and were characterised by blue eyes and light hair, but I was not prepared to find that their complexion was of that transparent whiteness which freckles readily and is supposed to mark the so-called red Kelt. They are dolichocephalic, and as their skulls agree with those discovered in the prehistoric cromlechs of Roknia and other places it is plain that their distinctive features are not due, as was formerly supposed, to intermixture with the Vandals.

The cromlechs in which they once buried their dead are quite as remarkable as their physical characteristics. Cromlechs of a similar shape are found extending through Spain and western France to the northern portion of the British Isles. Since dolichocephalic skulls occur in connection with them, while the physical characteristics of the modern Kabyle resemble so strikingly those of a particular portion of the modern Irish population, we seem driven to infer that the Kabyle and the 'red Kelt' are alike fragments of a race that once spread from Scotland and Ire-

land to the northern coast of Africa and interred its dead in chambers formed of five large blocks of stone. Though the custom of burying in these cromlechs continued into the bronze age, the majority of them go back to the neolithic period.

Are we to suppose, then, that one stream of Aryan immigrants, after making its way to the west, wandered along the western coast of Europe, and eventually crossed the Straits of Gibraltar and took possession of Africa? Or are we to believe that the Aryan race of southern Scandinavia was allied in blood, though not in language, with a population which inhabited the extreme west of Europe, and had, it may be, at the close of the glacial epoch, passed over to the neighbouring mountains of Africa? It must be remembered that the Kabyle complexion is not precisely the same as that of the Scandinavian. Both are white, but the skin of the one has a semitransparent appearance, while the whiteness of the other may be described as mealy. It will be worth while to determine whether between the dolichocephalism of the Kabyle and the dolichocephalism of the Scandinavian any distinction can be drawn.

The question has a bearing on the origin of a part of our own population. I have already compared the Kabyle with the 'red Kelt.' But the expression 'red Kelt,' like most popular expressions, is by no means exact. It confuses in one two distinct types. The large-limbed, red-haired Highlander, who calls to mind the description given of the Kelts by the Latin historians, stands in marked contrast to the small-limbed, light-complexioned Kelt of certain districts in Ireland, whose skin is freckled rather than burnt red by the sun. The determination of the several racial elements in these islands is particularly difficult on account of the intermixture of population, and nowhere is the difficulty greater than in the case of the Keltic portion of the community. Long before the Roman conquest the intrusive Aryan Kelt had been intermarrying with the older inhabitants of the country, who doubtless belonged to more than one race, the result being that the so-called Keltic race is an amalgamation of races differing physiologically but dominated by a common moral and intellectual character—the consequence of subjection for a long series of generations to the same conditions of life. It has become a commonplace of ethnology that the so-called Keltic race includes not only the fair-complexioned Aryan Kelt, but also the 'black Kelt' or Iberian with dark skin, black hair and eyes, and small limbs. The subject, however, is much more complex than this simple division would imply. We have seen that under the 'red Kelt' are included two distinct varieties; the 'black Kelt' is equally irreducible to a single type, while the fact that the two types of 'red' and 'black' recur in the same family—my own, for example—not only indicates their long-continued intermixture, but suggests the existence of intermediate varieties. The limitations and relations of dolichocephalism and brachycephalism within the race also need further investigation. I hope that this meeting, held as it is on the borders of what is still a distinctively Keltic country, may help to settle these and similar problems.

Meanwhile I will conclude this address, which has already extended to an inordinate length, by directing your attention to two lines of evidence which have an important bearing on the question of the extent to which the Keltic element enters into the existing British population. A few years ago it was the fashion to assert that the English people were mainly Teutonic in origin, and that the older British population had been exterminated in the protracted struggle it carried on with the heathen hordes of Anglo-Saxon invaders. The statement in the 'Saxon Chronicle' was quoted, that the garrison of Anderida, or Pevensey, when captured by the Saxons in A.D. 491, was all put to the sword. But it is obvious that the fact would not have been singled out for special mention had it not been exceptional, while it is equally obvious that invaders who came by sea can hardly have brought their wives and children with them, and must have sought for both wives and slaves in the natives of the island. Mr. Coote, in his 'Romans of Britain,' and Mr. Seebohm, in his 'English Village Community,' have pointed out the continuity of laws and customs and territorial rights between the Roman and the Saxon eras, presupposing a continuity of population, and anthropologists have insisted that the survival of early racial types in all parts of the country cannot be

accounted for by the settlement of the Bretons who followed William the Conqueror, or of the Welsh who came into England when the penal laws against them were repealed by Henry VIII. But the advocates of the theory of extermination had always one argument which seemed to them unanswerable, and which indeed was the origin of their theory. The language of the Anglo-Saxons contains scarcely any words borrowed from Keltic. Such a fact was held to be inexplicable except on the hypothesis that the speakers of the Keltic dialects were all exterminated before any intercourse was possible between them and the invading Teuton.

But I think I can show that the fact admits of quite another explanation. Roman Britain was in the condition of Roman Gaul; it was a Roman province, so thoroughly Romanised indeed that before the end of the first century, according to Tacitus ('Agric.' 18–21), even the inhabitants of North Wales had adopted the Roman dress and the Roman habits of luxury. After four centuries of Roman domination it is not likely under these circumstances that the dialects of the British tribes would have resisted the encroachment of the Latin language any more than did the dialects of Gaul. The language, not only of government and law, but also of trade and military service, was Latin, while the slaves and servants who cultivated the soil were bound to understand the language of their masters. Moreover, Britain was a military colony; the natives were drafted into the army, and there perforce had to speak Latin. If Latin had not been the language of the country at the time the Romans left it, the fact would have been little short of a miracle.

That it was so is certified by more than one piece of evidence. The inscriptions which have survived from the period of the Roman occupation are numerous; with the exception of three or four Greek ones, they are all in Latin. Of a Keltic language or dialect there is no trace. When the Romans had departed, and the inhabitants of Wales and Cornwall had been cut off from intercourse with the civilised world, Latin was still the ordinary language of the mortuary texts. It is only gradually that Keltic oghams take their place by the side of the Roman characters. When St. Patrick writes a letter to the Welsh prince of Cardiganshire, addressed not only to him but to his people as well, it is in the Latin language; when St. Germanus crosses into Britain to settle a theological controversy, and leads the people to victory against the Saxon invader, he has no difficulty in being understood; and the proper names of the British leaders continue to be Roman long after the departure of the Roman legions. What clinches the matter, however, is the positive statement of Gildas, the British writer, the solitary witness who has survived to us from the dark period of heathen invasion. He asserts that the ships called 'keels' by the Saxons were called *longæ naves* 'in *our* language' ('nostra lingua').[1] In the middle of the sixth century, therefore, Latin was still the language of the Kelt south of the Roman Wall. Such being the case, it is not Keltic but Latin words that we must expect to have been borrowed by Anglo-Saxon, if the British population, instead of being exterminated, lived under and by the side of their Teutonic invaders. Now these borrowed Latin words exist in plenty. They have come not only from the speech of the towns, but also from the speech of the country, proving that the country population must have used Latin like the inhabitants of the towns. In an interesting little book by Professor Earle on the Anglo-Saxon names of plants a list is given of the names of trees and vegetables that have been taken from a Latin source. Where the tree or the vegetable was one with which the invaders had not been acquainted in their original home, the name they gave to it was a Latin one, like the *cherry* or *cerasus*, the *box* or *buxus*, the *fennel* or *feniculum*, the *mallow* or *malva*, the *poppy* or *papaver*, the *radish* or *radix*. Such names they could have heard only from the serfs who tilled the ground for their new lords, not from the traders and soldiers of the cities. It is much the same when we turn to the names of agricultural implements which imply a higher order of culture than the simple plough or mattock, the name of which last, however, is itself of Keltic origin. Thus the coulter is the Latin *culter*, the sickle is the Latin *secula*. That other agricultural implements bore Teutonic names

[1] *Hist.* 23.

proves merely that the Saxons and Angles were already acquainted with them before they had quitted their primitive seats.

The philological argument has thus been cut away from under the feet of the advocates of the theory of extermination, and shown to tell precisely the contrary tale. It has disappeared like the philological argument by which the theory of the origin of the Aryans in Asia was once supposed to be supported. But there still remains one difficulty in our path.

This is the fact that the languages spoken in Wales, and till recently in Cornwall, are Keltic and not Latin. If Latin had been the language of the Keltic population of southern Britain when the Romans left the island, how is it that where the Keltic population still retains a language of its own that language is Keltic? The answer to this question is to be found in history and tradition. Up to the sixth century the Teutonic invaders gained slowly but steadily upon the resisting Britons. They forced their way to the frontiers of what is now Wales, and there their further course was checked. The period when this took place is the period when Welsh literature first begins. But it begins, not in Wales, but in Strathclyde or south-western Scotland, to the north of the Roman Wall. Its first records relate to battles that took place in the neighbourhood of Carlisle. From thence its bards and heroes moved southwards into North Wales. Tradition commemorated the event as the arrival in Wales of 'Cunedda's men.' The sons of Cunedda founded the lines of princes who subsequently ruled in Wales, and the old genealogies mark the event by suddenly substituting princes with Welsh names for princes with Latin names. The rude Keltic tribes of Strathclyde came to the assistance of their more cultured brethren in the south, checking the further progress of the foreigner and imposing their domination and language upon the older population of the country. It is probable that the disappearance of Latin was further aided not only by the destruction of the cities and the increasing barbarism of the people, but also by the settlement of Irish colonies, more especially in South Wales. At all events the ruin of cities like Caerleon and Caerwent must be ascribed to Irish marauders. We can now explain why it is not only that Wales speaks Welsh and not Latin, but also why a part of the country, which, according to Professor Rhŷs, was mostly peopled by Gaelic tribes before the Roman conquest, speaks Cymric and not Gaelic. As for Cornish its affinities are with Breton, and since history knows of frequent intercourse between Cornwall and Brittany in the age that followed the departure of the Romans we may see in the Cornish dialect the traces of Breton influence.

The arrival of 'Cunedda's men' and the re-Keltisation of Wales lead me to the second line of evidence to which I have alluded above. The bearing of the costume of a people upon their ethnography is a matter which has been much neglected. But there are few things about which a population—more especially in an early stage of society—is so conservative as in the matter of dress. When we find the Egyptian sculptor representing the Hittites of the warm plains of Palestine clad in the snow-shoes of the mountaineer we are justified in concluding that they must have descended from the ranges of the Taurus, where the bulk of their brethren continued to live, just as the similar shoes with turned-up ends which the Turks have introduced among the upper classes of Syria, Egypt, and northern Africa point to the northern origin of the Turks themselves. Such shoes are utterly unsuited for walking in over a country covered with grass, brushwood, or even stones; they are on the contrary admirably adapted for walking on snow.

Now the dress of Keltic Gaul and of Southern Britain also when the Romans first became acquainted with it was the same as the dress which 'linguistic palæontology' teaches us had been worn by the primitive Aryans in their first home. One of its chief constituents were the *braccæ*, or trousers, which accordingly became to the Roman the symbol of the barbarian. We learn, however, from sculptures and other works of art that before the retirement of the Romans from the northern part of Europe they had adopted this article of clothing, at all events during the winter months. That the natives of southern Britain continued to wear it after their separation from Rome is clear from a statement of Gildas ('Hist.' 19) in which he refers in no flattering terms to the kilt of the Pict and the Scot. Yet

from within a century after the time of Gildas there are indications that the northern kilt which he regards as so strange and curious had become the common garb of Wales. When we come down to the twelfth century we find that it is the national costume. Giraldus Cambrensis gives us a description of the Welsh dress in his own time, from which we learn that it consisted simply of a tunic and plaid. It was not until the age of the Tudors, according to Lluyd, the Welsh historian of the reign of Elizabeth, that the Welsh exchanged their own for the English dress.[1] The Welsh who served in the army of Edward II. at Bannockburn were remarked even by the Lowland Scotch for the scantiness of their attire,[2] and we have evidence that it was the same a century later.[3] If we turn to Ireland we find that in the days of Spenser, and later, the national costume of the Irish was the same as that of the Welsh and the Highland Scotch. The knee-breeches and sword-coat which characterise the typical Irishman in the comic papers are survivals of the dress worn by the English at the time when it was adopted in Ireland.

The Highland dress, therefore, was once worn not only in the Scotch Highlands and in Ireland, but also in Wales. It characterised the Keltic parts of Britain with the exception of Cornwall and Devonshire. Yet we have seen that up to the middle of the sixth century, at the period when Latin was still the language of the fellow-countrymen of Gildas, and when 'Cunedda's men' had not as yet imposed their domination upon Wales, the old Keltic dress with trousers must have been the one in common use. Now we can easily understand how a dress of the kind could have been replaced by the kilt in warm countries like Italy and Greece; what is not easily conceivable is that such a dress could have been replaced by the kilt in the cold regions of the north. In warm climates a lighter form of clothing is readily adopted; in cold climates the converse is the case.

I see, consequently, but one solution of the problem before us. On the one hand, there was the distinctive Keltic dress of the Roman age, which was the same as the dress of the primitive Aryan, and was worn alike by the Kelts of Gaul and Britain and the Teutons of Germany; on the other hand, there was the scantier and colder dress which originally characterised the coldest part of Britain, and subsequently mediæval Wales also. Must we not infer, in the first place, that the aboriginal population of Caledonia and Ireland was not Keltic—or at least not Aryan Keltic—and, secondly, that the dominant class in Wales after the sixth century came from that northern portion of the island where the kilt was worn? Both inferences, at all events, agree with the conclusions which ethnologists and historians have arrived at upon other grounds.

Perhaps what I have been saying will show that even a subject like the history of dress will yield more results to ethnological study than is usually supposed. It will be another illustration of the fact that the student of humanity cannot afford to neglect any department of research which has to do with the life of man, however widely removed it may seem to be from science and scientific methods of enquiry. 'Homo sum; humani nihil a me alienum puto.'

The following Papers were read:—

1. *The Primitive Seat of the Aryans.* *By* Canon Isaac Taylor, *LL.D., Litt.D.*

In this paper the author discussed recent theories as to the region in which the Aryan race originated. The prescientific Japhetian theory and the Caucasian theory of Blumenbach have long been abandoned. A few years ago the theory advocated by Pott, Lassen, and Max Müller, which made the highlands of Central Asia the cradle of the Aryans, was received with general acquiescence, the only protest of note coming from Dr. Latham, who urged that the Asiatic hypothesis was mere assumption based on no shadow of proof. The recent investigations

[1] *The Breviary of Brytaine*, Twyne's translation, p. 35 (ed. 1573).

[2] Barbour's *Bruce*, ix. 600–603.

[3] See Jones, *History of the County of Brecknock*, vol. i. p. 283; comp. *Archæologia Cambrensis*, 5th ser. No. 7 (1885), p. 227.

of Geiger, Cuno, Penka, and Schrader have brought about an increasing conviction that the origin of the Aryan race must be sought not in Central Asia, but in Northern Europe. These writers have urged that the evidence of language shows that the primitive Aryans must have inhabited a forest-clad country in the neighbourhood of the sea, covered during a prolonged winter with snow, the vegetation consisting largely of the fir, the birch, the beech, the oak, the elm, the willow, and the hazel; while the fauna comprised the beaver, the wolf, the fox, the hare, the deer, the eel, and the salmon—conditions which restrict us to a region north of the Alps and west of a line drawn from Dantzic to the Black Sea.

It has also been urged that the primitive Aryan type was that of the Scandinavian and North German peoples—dolichocephalic, tall, with white skin, fair hair, and blue eyes, and that those darker and shorter races of Eastern and Southern Europe who speak Aryan languages are mainly of Iberian or Turanian blood, having acquired their Aryan speech from Aryan conquerors. It has been urged that the tendency in historic times has been to migration from north to south, the inhabitants of the fertile and sunny regions of Southern Europe, where the conditions of life are easy, having no inducements to migrate to the inhospitable north. Moreover, in Central Asia we find no vestiges of any people of the pure Aryan type, while the primitive Aryan vocabulary points to the fauna and flora of Northern Europe rather than to that of Central Asia.

Fair races have a greater tendency to become dark in a southern clime than dark races to become fair in northern regions, as is proved by the fact that the complexion of the polar peoples, such as the Eskimo, the Lapps, and the Samojeds, has been unaffected by their sojourn for uncounted centuries in the north, while there is much evidence to prove that the noble classes in the Mediterranean lands were formerly lighter in colour than at present.

A vast body of evidence, of which the foregoing is a brief summary, has been adduced to show that Northern Europe rather than Central Asia was the home of the undivided Aryan race.

But the Aryans must have had forefathers from whom they were developed, and the inquiry suggests itself, what could have been the race from which the Aryans might have been evolved? A Semitic, an Iberian, an Egyptian, a Chinese, a Turkic, or a Mongolic parentage is out of the question, and the author proposed to show that, both from the anthropological and the linguistic point of view, the Finnic people come closest to the Aryans, and are the only existing family of mankind from which the Aryans could have been evolved. The Tchudic branch of the Finnic family approaches very nearly to what we must assume to have been the primitive Aryan type. The Tchuds are either mesocephalic or dolichocephalic. They are a tall race, the hair yellow, reddish, or light brown, the skin white, while blue or grey eyes are usual. As we go westward from the Baltic we find that the Ugro-Finnic tribes approximate more and more to the Turko-Tatar ethnic type, just as when we go southward the southern Aryans conform increasingly to the Iberian type. Hence in the Baltic provinces of Russia we discover what seems to be the centre of dispersion, a region where the ethnic characteristics of Finns and Aryans do not greatly differ. Of this fact only two explanations are possible. Either the Baltic Finns have been Aryanised in blood while retaining their Finnic speech—an hypothesis supported by no evidence, and in itself improbable—or else we have here in their original seats a survival of the people from whom the Aryans were evolved. Anthropological considerations tend therefore to show that the Aryans are an improved race of Finns, while on the other hand the Finnic speech approaches more nearly than any other to the Aryan, and is the only family of speech from which the Aryan languages can have been evolved.

The chief argument for deriving the proto-Aryans from Central Asia was the belief that Sanskrit comes the nearest to the primitive Aryan speech. It is now believed the Lithuanian, a Baltic language, represents a more primitive form of Aryan speech than Sanskrit, and hence the argument formerly adduced in support of the hypothesis that the Aryans originated in Central Asia becomes an argument in favour of Northern Europe.

The separation of the Aryan from the Finnic races must have taken place at a

period so remote that we cannot expect to find any marked identity in their vocabulary. The words common to the Aryan and Finnic tongues are, for the most part, loan words. But the words denoting the primary relations of life, the names for father, mother, son, daughter, brother, and sister, can hardly be loan words, and these are substantially identical in the Finnic and Aryan languages. The same is the case with a few of the numerals, the pronouns, and the names for some of the primary necessities of life, such as the words denoting salt, shelter, food, and the rudest implements. But when we go back to the verbal roots which constitute the very basis of language, we find a remarkable identity between the Aryan and Finnic tongues. Thus the eighteen triliteral roots beginning with *k*, given in Skeats' 'Etymological Dictionary,' are all found in Finnic with the same fundamental signification. It is quite incredible that this identity in the ultimate roots can be accidental. Both in Aryan and Finnic these verbal roots are combined with formative suffixes to form nominal stems. We have the same formatives with the same significations. The conjugation of the verb is also effected in the same way by the addition of identical pronominal suffixes to the verbal roots. The accusative, the ablative, and the genitive, which appear to be the three original cases, are formed in similar fashion by the addition of identical post-positions. The only fundamental differences between Aryan and Finnic grammar lie in the absence of gender in the Finnic languages, and in the wholly different formations of the plural. But Professor Sayce has shown reasons for believing that the proto-Aryan speech possessed no gender, thus agreeing with its Finnic prototype; and he also believes that it possessed only the dual, the plural being a later development. But the dual is formed in precisely the same manner in the Aryan and Finnic languages, while the comparatively recent origin of the Finnic plural is proved by the fact that in the Finnic and the allied Turkic languages the plural is diversely formed.

Hence the proto-Finnic speech agrees in every respect, both as to the grammar and the roots, with the proto-Aryan speech, and there is therefore no difficulty in the supposition that the one represents an archaic stage out of which the other was developed.

These considerations modify considerably our conceptions as to the way in which we may conjecture that the Aryan race originated. Instead of supposing a single Aryan tribe in Central Asia, which sent off successive swarms to the west and south, we may rather conceive of the whole of Northern Europe, from the Rhine to the Vistula, as occupied by a Finnic race, whose southern and western members gradually developed ethnic and linguistic peculiarities of that higher type which we associate with the Aryan name. The Baltic Finns are survivals of this race. The Celts, owing to their remoteness, diverged at an early time from the eastern type, while the Lithuanians and the Hindus preserved many archaic features both of grammar and vocabulary. The Slaves must be regarded mainly as Ugrians, and the South Europeans as Iberians, who acquired an Aryan speech from Aryan conquerors. The time of the separation of the Aryan from the Finnic stock must be placed at the least 5,000, or perhaps even 10,000 years ago. At that time the linguistic evidence shows that the united peoples possessed only the rudiments of civilisation. Of the metals they possibly knew gold and copper, but their tools were mainly of stone or horn. They sheltered themselves in rude huts, they knew how to kindle fire, they could count up to ten, and family relations and marriage were recognised. They were acquainted with the sea, they used salt, and they caught salmon; but it is doubtful whether they were acquainted with the rudiments of agriculture, though they gathered herbs for food and collected honey. They possessed herds of domesticated animals, consisting probably of oxen and swine, and perhaps of reindeer, but the sheep seems to have been unknown.

If this hypothesis as to the primitive identity of the Aryan and Finnic races be established, a world of light is thrown upon many difficulties as to the primitive significances of many Aryan roots and the nature of the primitive Aryan grammar. We are furnished, in fact, with a new and powerful instrument of philological investigation, which can hardly fail to yield important results. Comparative Aryan philology must henceforward take account of the Finnic languages as affording the oldest materials which are available for comparison.

2. *The Non-Aryan and Non-Semitic White Races, and their Place in the History of Civilisation.* By J. S. STUART-GLENNIE, *M.A.*

The general thesis of this paper may be thus stated. The first civilisations of Chaldea and of Egypt appear to have been founded by the action on dark races of white races, neither Aryan nor Semitic. The combined results of a great variety of recent researches show that such white races are an important, and hitherto quite inadequately recognised, element in the ethnology of Asia, and of Oceania, of Africa, of Europe, and of America; and not only in Chaldea and in Egypt, but throughout the world, the civilisations of Semites and of Aryans have been founded on civilisations initiated by some one of these non-Aryan and non-Semitic, or, as in one word they may, perhaps, fitly be called, Archaian white races.

The three great divisions of this paper are indicated by this statement of its thesis:—

First, classification and summary of the facts which seem to lead to the conclusion that the initiators of the Chaldean and Egyptian civilisations belonged to a white stock different from both the Aryan and the Semitic white stock.

Secondly, an endeavour to give an approximately complete indication, at least, if not statement, of the facts only partially stated by Quatrefages (*Hommes fossils et hommes sauvages*) with respect to the white races which he names *Allophyllian*, and for which the term *Archaian* is proposed.

Thirdly, classification and summary of the facts which—the wide dispersion of an Archaian stock of white races being established—seem to indicate that the vexed questions with respect to the Hittites, the Pelasgians, the Tyrrhenians, the Iberians, the Picts, &c., and with respect also, in part, to the origin of the Chinese, the Mexican, and the Peruvian civilisations—the facts which indicate that these questions may be solved by reference to the general facts with regard to the migrations and characteristics of the Archaian white races.

The bearing of these results on the questions raised by the essential identity of the varying forms of folklore tales all over the world are also pointed out.

3. *On the Picture Origin of the Characters of the Assyrian Syllabary.* By the Rev. W. HOUGHTON.

All written language probably originated in pictures representing objects or ideas, as in Chinese and Egyptian. At first the characters were rude figures of animals or other objects. In time the resemblance would be fainter, till at length all similarity between the character and the object represented would disappear. This process may be expressed by the term 'pictorial evanescence.' Of the 522 characters of the Assyrian syllabary, as given in Professor Sayce's Grammar, very few of the simple characters exhibit their primitive form, but the composite characters often clearly reveal themselves. We must look to the older forms of the characters for evidences of their pictorial origin. Thus, the character for a 'fish' in the modern Assyrian may be traced back through the hieratic Assyrian, the hieratic Babylonian, and the linear Babylonian to a figure of a fish, with head, body, fins and tail. The ideograph for a 'month' is in its ancient form a figure of a square with 3×10 inside it—*i.e.*, thirty days within the sun's circle. The ancient forms of the character denoting a 'man' are rude figures of a man with head, neck, shoulders, body, and legs—such a picture as a schoolboy would draw on his slate, or the North American Indians depict.

4. *Wusum and other Remains in Egyptian Arabia.* By COPE WHITEHOUSE, *M.A.*

In March 1887 the author accompanied Major Surtees on a political mission to the south-eastern frontier of Egypt, in Arabia, and the frontier of the Hedjaz. It is guarded by a modern fort, whose crumbling walls were photographed while a gun was being fired; and by a solid straight-curtained fortress,

five miles to the west, on the pilgrim road to Medina and Mecca, with an inscription of Ahmed ibn-Tulun (A.D. 868–894). Up the valley to the north-east, scratched in greenstone porphyry, are 'so-called' *Wusum*, or 'tribal marks' (photographs shown). Further to the west are the 'Gold Mines of Midian' of Sir R. Burton. There are three mistakes in this appellation. The quartz is not auriferous; the holes are not mines; the region was never called Midian. To the south, in the Wadi Hamz are ruins of a Greco-Roman temple, near a Gebel Kibrīt or sulphur mountain, interesting as the only Greco-Roman ruins ever found in Arabia. Photographs of these were also shown.

FRIDAY, SEPTEMBER 2.

The following Report and Papers were read:—

1. *Report of the Committee for procuring Racial Photographs from the Ancient Egyptian Pictures and Sculptures.*—See Reports, p. 439.

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2. *Notes on the Accuracy of the Sculptures and Paintings of Races on the Egyptian Monuments. By* W. M. FLINDERS PETRIE.

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3. *Studies on some Groups of Mr. W. M. Flinders Petrie's Casts and Photographs of Ethnographic Types from Egypt,* 1887.[1] *By the* Rev. HENRY GEORGE TOMKINS.

The paper treats of local points of interest in Mr. Petrie's collection geographically and ethnologically, under the four heads: I. *Westerns*; II. *Southerns*; III. *Northerns*; IV. *Egyptians*.

I. WESTERNS.—*Tahennu.* The clear-complexioned races. *Ha-nebu.* People of Mediterranean isles and coasts (later applied to Greeks). *Lebu.* Libyans, of Hamitic stock. Early doings as enemies, tributaries, subjects, invaders; founders of an Egyptian dynasty. *Mashuasha.* Maxyans. Personal appearance, supposed connection with Northern Syria. *Dardani.* Trojan leaders, afterwards succeeded by *Tsekkriu.* Teukrians, in time of Râmeses III. *Shakalsha,* Sicilians. *Tuirsha,* Tyrsenes, Etruscans. *Pulista.* Pelasgians, Philistines (?).

II. SOUTHERNS.—*Cush.* Among the four typical races. Deshfu, Turses, Tarau, Arma, Awawa, Adal, M'ām, Khāma. *Pûn,* where? A list of eighteen places, with heads of chiefs, considered. *Ezek.* xxvii. 19, 20, Yavan of Arabia, &c. Queen Hatasu's expedition, whither, and the port. The incense trees identified. Her palace-temple at Deïr-el-Bahri and its style. The tomb of Hûi. A group of Pûnite nobles considered.

III. NORTHERNS.—*Menti of Sati,* who? *Shāsu,* Arabs. Their extent and historical importance. *Rutens, Lower and Upper,* Syria. *Lemenen,* Lebanon, its people. *Khal* or *Khar,* Northern Syria. *Keft,* Phœnicia, and its people. *Am'ār,* the Amorite in, and out of, the Bible; their extent, affinities, and history. *Kheta,* the Hittites, considered. Their characteristics and connections.

Asqaluna.—*Kan'āna* and its defenders, where? *Dapur,* Tabor. Its fortress and defenders. *Bita-Anta,* Beth-Anath. *Marm,* Merom, its people. *Dimesqu,* Damascus. The Karnak lists of Thothmes III. Their very high interest and importance. *Ianu,* where? Shishak's list. *Khāniniā.* *Adir.* *Yudah-melek,* the celebrated name and head, considered.

IV. EGYPTIANS.—The old kingdom. The XIIth dynasty. The Hyksôs. The Patriots and their success. The XVIIIth dynasty. Hatasu, Thothmes III. Khu-

[1] This paper is printed (in an abridged form) as an appendix to the Report on Mr. Flinders Petrie's Collection of Ethnic Types.

en-aten and his connections considered. The Ramessids. The priest-kings. The XXIInd dynasty, called Bubastite. Various types recounted, and remarks on the whole matter considered as a subject of study and of educational information.

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4. *Boat-shaped Graves in Syria.*[1] *By* GEORGE ST. CLAIR, *F.G.S.*

In passing through the Anti-Lebanon lately, from Damascus to Baalbec, the writer noticed that the graves at the hamlet of *El Fijeh* have the form of a flat-bottomed boat; those at *Ain Hawar* are formed like long narrow boats, with an ark or house occupying the middle part; and the graves at the village of *Yafufeh* are built in three tiers, of which the upper one may be representative of the ark, while the head- and foot-stones are almost certainly the conventional reproduction of the head and stern of the boat.

The author asks the question: What led these people in the mountains to build their graves on the model of a boat? Authors are quoted to show that arks or ships were carried in procession by the Phœnicians, as also were sacred boats in the funeral processions of the ancient Egyptians. The Egyptians conveyed the body across a lake, and both the lake and the boat were symbolical, typifying the voyage of the Soul in the Underworld.

The system passed into Greece, where we have Charon and his boat. Charon's boat is sculptured on a funeral monument in the Ceramicon at Athens—a recently uncovered cemetery; and the bas-relief of a ship appears on a tomb at Pompeii. From these facts and others the writer of the paper would infer that the boat-shaped graves of Syria are fashioned by traditional custom in perpetuation of a practice which appears to have originated with the ancient Egyptians.

As a supplementary conclusion, it is suggested that the head-stones and foot-stones of modern graves may be the surviving representatives of the prow and poop of the sacred boat of the dead.

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5. *On* 108 *Skulls from Tombs at Assouan.* *By* W. S. MELSOME.

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6. *Account of a 'Witch's Ladder' found in Somerset.* *By* DR. EDWARD B. TYLOR, *F.R.S.*

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7. *The Effect of Town Life upon the Human Body.* *By* J. MILNER FOTHERGILL, *M.D.*

It is generally recognised that the effect of town life upon the physique is not beneficial; and as the population of boroughs has now exceeded that of the country the fact becomes one worthy of our attention. The great and rapid increase of large towns at the present time adds to the importance of the subject and deepens its gravity.

Of old there were but few large towns, in our modern sense of a 'large' town; but Lugol, the great French authority on 'scrofula,' noted how the population of Paris deteriorated, and how scrofulous were the third generations of persons who came in from the country perfectly healthy. Other observers have noticed the bad effect of town life elsewhere. And the recent researches of Mr. James Cantlie have demonstrated the rarity of a pure-bred Cockney of the fourth generation. If physical deterioration and early extinction are the fate of town dwellers—and of that there seems no question—it behoves us next to inquire as to the how and the why of it all.

It may be well to begin by contrasting the actual circumstances of country life and of town life. Of old the baron lived in his castle, while the populace lived around in villages of limited size. For men of all conditions of life the one thing

[1] This paper is printed *in extenso* in the *Quarterly Statement* of the Palestine Exploration Fund, October 1887.

to be coveted above all others was physical prowess. For work, for war, for games which were largely mimic war, bodily strength was essential. No courage, no skill could effectually compensate for the want of thews and sinews. Work, war, sports, revels, all, too, were conducted in the open air. But civilisation brought about changes profoundly influencing the life of the individual. The development of commerce entailed the growth of towns; and then it was found that in the new struggle for existence the battle went rather to the man with the active brain than the man with a massive framework. The active brain became now the one great thing to be coveted rather than physical prowess.[1]

From this brief consideration of the altered life of the town dweller it may be well to take a step forward and consider some facts in regard to the development of the individual. At the very threshold of existence the embryo consists of three primitive layers. The outer one gives the brain and sensitive skin; in other words, the means by which the organism is in communication with its environment. The inner layer gives the glandular apparatus of organic life—the digestive organs. The middle layer gives the locomotor apparatus and, what more immediately concerns us at present, the vascular system. By means of the latter it feeds its own proper structures, and the outer and inner layer on either side of it.

In a country child the structures of the three layers wax and grow side by side with each other in due proportion. The child gambols about in the open air pretty much like the other young animals, with little to diversify the monotony of its existence or stimulate its nervous system. Thews and sinews, nervous system and digestive organs, keep pace with each other; not one growing at the expense of the rest. Far otherwise is it with the town child. 'You cannot eat your cake and have it' says the old adage. So it is with the growing town child. Instead of the quiet country road it has the crowded street with all the excitement connected therewith, the swiftly recurring incident, the chaff which gives it its charm with many. All this stimulates the nervous system. The self-possessed town child is a man or woman of the world, while the country child of like years is a bashful bumpkin, hiding behind its mother's dress. The town child eats too much of its cake daily and every day to have any great store. Its precocious nervous system makes such demands upon its nutritive powers that the rest of the body suffers. Say the three layers in the healthy country child stand thus: $3+3+3=9$; we find in the town child something like this: $2+2+3=7$. And in their ultimate development this is found to be the case as to weight. The town man may be said to weigh nine stones, while the country man averages eleven stones and one half.

The nervous system has grown at the expense of the other structures. The stature is dwarfed. The tendency of town populations is to dwindle, and this dwindling is seen markedly in the feeble digestive capacity of town dwellers. They cannot eat the pastry, the pie-crust, the cakes which form so large a portion of the dietary of their country cousins. If they attempt these articles of food they give themselves the stomach-ache. Consequently they live on such food as they can digest without suffering—bread, and fish, and meat. Above all the last—the sapid, tasty flesh of animals, which sits lightly on the stomach, and gives an acceptable feeling of satiety, so pleasant to experience. The town dweller, in his selection of food, is guided by his feelings; he avoids what is repugnant to him. Such selection is natural and intelligible, but it is fraught with danger all the same.

Let us now consider what these dangers are. He loathes fat, especially in the solid form of animal fat. Every bit is carefully cut away from the lean and rejected. Possibly this in some instances is due to silliness, which decides that it is not the proper thing to eat fat. Far more frequently, it is to be feared, the rejection is based on an instinctive feeling that it cannot be digested. Else why should delicate children turn away from sweet animal fat with loathing, and yet take readily enough the nauseous fishy cod-liver oil—the most digestible form of fat? When a patient about to die of consumption can take cod-liver oil,

[1] The effects of mental activity upon the physique are not included in the present paper.

often his doom is deferred and very frequently averted. The absence of fat in the dietary predisposes the town dweller to phthisis. The prevalance of consumption among town populations is notorious. But there is another grave malady also seen to be more and more frequent among town dwellers, viz., the disease commonly spoken of as 'chronic Bright's disease.' It has been said before that the town dweller does not eat cakes, pastry, and pie-crusts because they give him pain. He eats fish, bread, and meat. We have just considered the effects of an absence of fat in the dietary; now we must estimate the effects of an excess of meat in it. Meat ultimately escapes from the body by the kidneys. When a dietary consists too largely of meat sundry evil consequences follow. Gout is one, chronic Bright's disease is another; and the two are very commonly found together. In the form of uric acid this excess of excrementitious matter sets up a widespread change in the vascular system and the kidneys. It has been proposed to apply the term 'vasorenal' to the widespread pathological process involving numerous maladies as outcomes of it. Uric acid is derived from the albuminous elements of our food, of which the flesh of animals is the type. From its digestibility meat is chosen by the town dweller in ignorance of the danger underlying indulgence in it. Normally the bulk of nitrogenised matter is excreted as soluble urea. When the work of the liver is too much for that viscus it reverts or falls back upon the primitive uric acid formation. The congenitally feeble liver—part of the imperfect digestive organs—of the town dweller feels the burden of a dietary rich in albuminoid elements. The formation of the comparatively insoluble uric acid becomes established, and with it many morbid sequences; including chronic change in the kidneys, set up by the irritation of the uric acid constantly passing through them. Such changes must have gone on from the dawn of history, but they are most marked amidst degenerating town populations.

Pulmonary phthisis and Bright's disease seem Dame Nature's means of weeding out degenerating town dwellers. The offspring of urban residents are another race from their cousins who remain in the country. The latter are large-limbed, stalwart, fair-haired Anglo-Danes; while their urban cousins are smaller, slighter, darker beings, of an earlier and lowlier ethnic form, and resembling the Celto-Iberian race. And amidst this general reversion we can recognise a distinct liver-reversion to the early primitive uric acid formation of the bird and reptile.

A recognition of these facts must lead to such modifications of the food customs of town dwellers as are indicated. The spread of teetotalism and vegetarianism tells of a dark groping in the right direction; in blind obedience to the law of self-preservation. It must also lead to some modification of the existing system of education for it is by the imperfectly nourished town child that the weight of the burden of education is most acutely felt.

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8. *On the Bosjes Pelvis. By* Professor CLELAND, *F.R.S.*

The unbroadened brim found in certain savage tribes is a retention of a feature of adolescence. This is seen well in the Bosjes, and the peculiarity may be correlated with others which have escaped attention. There is feeble development of the iliac blades, especially at the back part, probably owing to early anchylosis of the epiphysis of the crest. Connected with this the post-auricular levers of the ilia are very feeble, as they also are in early life in Europeans, causing shallowness of the post-sacral fossa occupied by the strongest part of the multifidus spinæ muscle, a most important muscle for erecting the lumbar part of the column on the pelvis. The action of the iliac levers in broadening the brim in the European is recognised. Their shortness, and the lightness of the superincumbent weight of the body, are circumstances which account for the brim failing to broaden out in the Bosjes.

SATURDAY, SEPTEMBER 3.

The following Papers and Reports were read:—

1. *The Experimental Production of Chest-types in Man. By* G. W. Hambleton.

The object of this paper was to place the following facts before the Association, in the hope that the important points they raise may form the subject of further investigation by a committee appointed for that purpose.

Whilst engaged in research the author's attention was drawn to the fact that the size and shape of the chest varied as he varied the conditions to which it was subject. He ascertained that this sequence of events was absolutely constant, and could be carried out within such wide limits that it appeared to him to present an insuperable objection to the present accepted theory of the inheritance of chest-types. Taking a well-marked example of the so-called inherited consumption chest, he subjected it to conditions that tend to develop the lungs till it corresponded in size and shape first with that of the town artisan, then with that of a man of the privileged class, and finally with that of a man of the best class of insurable lives in America. By subjecting that same chest to conditions that tend to reduce the breathing capacity, the author brought it back through the same types to nearly that with which he commenced. And similar results were obtained on other chests. Evidence was adduced showing that there is the same relationship between the size and shape of other parts of the body and the conditions to which they are subject; therefore the author contended that the type of man after birth was solely produced by the conditions to which he is subjected. Hence the formation of race and the return of man, animal, or plant to former types on being subjected to the conditions that produced that type.

This opens up a wide and most important field for our investigation. We have to ascertain what the conditions are that produce those changes in each part of man that together form a class or type, so that we may produce the type that is most suitable for different places and occupations, and then we shall have a Science of Man.

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2. *The Scientific Treatment of Consumption. By* G. W. Hambleton.

At the last meeting of the Association the author read a paper on that part of his research that referred to the prevention of consumption, and he now completed the subject by giving an explanation of the mode in which the disease is produced, and by laying down the principles that must guide us in its successful treatment

Whether there are any means by which we can be certain of successfully treating consumption is a question of such grave importance, and the author's contention in the affirmative is so entirely opposed to the results of treatment—with one too long forgotten great exception—that it was necessary to draw attention to the whole evidence that can be adduced in support of that contention.

The case may be conveniently divided into three branches, dealing with the cause of the disease, its mode of operation, and the principles of treatment. Taking these in their natural order we come first to the consideration of the cause of the disease, and the theory held by the author is this: that consumption is the direct result of the reduction of the breathing surface of the lungs below a certain point in proportion to the remainder of the body, and is solely produced by conditions that tend to reduce the breathing capacity.

In support of that interpretation of the cause of consumption the following evidence was adduced: (A) that referring to the known production of the disease by such conditions in certain trades and occupations, its experimental production in animals, evidence of the effect of such conditions in the disease itself, and the absence of a recorded case, experimental or other, in which such conditions were not present.

(B) That referring to the known absence of consumption in the absence of such conditions, and (C) that referring to the known introduction of such conditions being invariably followed by the appearance of the disease.

Theory of the mode in which consumption is produced. The first step is the reduction of the lungs to such an extent that they have not only lost their power of adjustment to their external conditions, but are also no longer able to perform their ordinary functions. Interchanges uneffected are thrown on one or more of the other organs. Process of reduction continues and a time comes when compensatory work is not effected. Greater pressure on the lungs which tells on the weaker parts, producing the phenomena of irritation, manifested by tubercular change. Each centre of change produces an additional factor in the process of reduction. Hence more irritation, followed by further reduction, till there is not sufficient lung left to perform those functions without which life cannot continue.

Having ascertained the cause of consumption and traced the mode in which it operates from the commencement to its termination, we are in a position to lay down the principles that must guide us in the adequate treatment of the disease.

They are four in number, and may be stated as follows:—

To establish an equilibrium between the amount of interchange required to be effected and that effected.

To enable the other organs of the body to perform their ordinary functions.

To restore to the lungs the power of adjustment to their external conditions.

And to effect the above without producing indications of friction.

The effect of this method of treatment is to arrest the process of irritation, to gradually restore the general health, and to develop the lungs. This is shown by a gradual cessation of chest symptoms, a healthy appearance, and a greatly increased vital capacity, range of expansion and size of chest-girth. The author has invariably obtained these results in his experiments, and also in the few cases he has had an opportunity of treating.

In the literature of consumption are found a multitude of cases in which a temporary arrest had been effected, and a careful examination of the conditions under which that occurred proves that they were invariably those that tended to remove the irritation by effecting a temporary adjustment between work to be done and work effected associated with others tending to develop the lungs. Further, many cases of absolute recovery are recorded, and in them also there were the same conditions acting continuously for a long time. Sydenham undoubtedly cured consumption by ordering continuous horse exercise in the country till the patient recovered. And the author is satisfied that if we carefully treat consumption—before the disease has been permitted to become too extensive—on the principles advocated in this paper we shall be able to secure complete recovery.

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3. *Ancient and Modern Methods of Arrow Release.* *By* Professor E. S. Morse.

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4. *Tattooing.* *By* Miss A. W. Buckland.

The object of this paper is to show that, although tattooing seems to have been almost universal among savages, yet the mode of performing the operation varies so much, and the various methods in use seem to have such definite limits, as to make them anthropologically valuable, as showing either racial connection or some intercourse formerly subsisting between races long isolated. In Africa, Australia, and some of the islands in the Indian Ocean, principally among the black races, tattooing consists of a series of short cuts, so treated as to leave cicatrices in various parts of the body. Colouring matter is not often employed, but on the west coast of Africa three cuts on the face seem to be a distinctive mark, and these, judging from the masks, &c., are coloured red and blue. These marks are either tribal or the sign of some secret society resembling freemasonry, and it is noteworthy that these three cuts are shown on the cheek of an ancient bronze head found at Bologna.

The method of tattooing in New Zealand, America, the Pacific Islands, among some of the tribes of India, Burmah, Borneo, New Guinea, and Japan, differs entirely from these cicatrices. The pattern is first drawn and afterwards punctured with needles, thorns, or often with sharp implements formed of human bone, and into the wounds thus made a pigment is rubbed, either of charcoal or more frequently of indigo blue, thus forming indelible marks, which sometimes cover the whole body and sometimes are confined to certain parts. In the men, tattooing of this kind denotes a chieftain or warrior, and is undergone as a test of courage and endurance, but the pattern is the totem, or emblem, of the tribe or individual. One great peculiarity is, that in almost all countries in which this form of tattooing exists, the women are tattooed on the chin, and this mark almost invariably denotes marriage. In connection with this, Miss Buckland pointed out that the custom seemed to follow the line of route indicated in her former papers on 'Prehistoric Intercourse between East and West' and 'American Shell-work,' thus corroborating the views therein expressed; and further called attention to a peculiar mark on the chin of a shell mask found in a grave-mound in Virginia, U.S.A., which is seen also on the chin of the great stone figure from Easter Island in the portico of the British Museum. In both cases this mark may probably denote tattooing, but whether in those remote times it was the distinctive mark of a female is not easily determined.

5. *Report of the Committee appointed to edit a new Edition of 'Anthropological Notes and Queries.'*—See Reports, p. 172.

6. *Third Report of the Committee for investigating and publishing reports on the physical characters, languages, and industrial and social condition of the North-Western Tribes of the Dominion of Canada.*—See Reports, p. 173.

MONDAY, SEPTEMBER 5.

The following Report and Papers were read:—

1. *Second Report of the Committee for investigating the Prehistoric Race in the Greek Islands.*—See Reports, p. 200.

2. *The Early Ages of Metal in South-East Spain. By* HENRI *and* LOUIS SIRET.

The authors explored a coast region, about 75 kilometers in length, between Cartagena and Almeria. They investigated some forty stations, belonging to *three* prehistoric epochs—(1) The Neolithic; (2) Transition between Stone and Metal; (3) Metal age. The following details are given:—

(1) In the *Neolithic* period man employs instruments in bone, stone, and flint; also the vases in baked earth, which characterise this age in other parts of Europe; ornaments of shells, bone, and stone used. The dead are buried in polygonal spaces, surrounded by stones.

(2) *Transition.*—Appearance of bronze bracelets and beads; cremation of the dead. These new customs imported by some foreign people. At the same time, evidence of the first attempts at a native metallurgy, utilising the ores of the country; arms and utensils cast in metal, imitating the form of those in bone and stone.

(3) *Metal* epoch.—Copper and bronze employed *simultaneously*, as in preceding age; but copper predominates. Stone implements still common. Silver appears: this is a *new* fact in the early Bronze age. In this region prehistoric man found

and utilised the native silver gathered on the surface of the soil. 1,300 sepultures explored ; *all* the bodies interred, and not cremated. Generally in large terra-cotta vases, in which the body is doubled up. Enormous quantity of copper and bronze arms and utensils ; of vases in pottery ; bracelets, rings, earrings, in copper, bronze, gold, silver ; necklace-beads in bone, ivory, serpentine, bronze, copper, silver, gold.

The following is a summary enumeration of the objects found by the authors :— 400 flint knives ; 150 flint arrowheads ; 700 flint saws ; 80 axes of polished stones ; 200 whetstones ; 300 various stones—polishers, discs, hammers, moulds, &c. ; 900 awls and other implements in bone and ivory ; 70 flat copper axes ; 300 copper and bronze knives and daggers ; 4 bronze swords ; 140 copper arrowheads ; 4,000 necklace-beads in stone, shell, bone, ivory, copper, bronze, silver, gold, &c. ; 400 borers in copper, bronze, silver ; 700 bracelets, rings, and pendants in bronze and copper ; 400 bracelets, rings, and pendants in silver ; 8 bracelets, rings, and pendants in gold ; 7 diadems in silver ; 1,300 terra-cotta vases, of which two-thirds are entire vases ; 500 perforated shells, &c. A very important and complete monography relating all these discoveries has just been published in Antwerp.

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3. *The Origin of Totemism.*[1] *By* C. STANILAND WAKE.

The term *totem* signifies the device of a gens or tribal division, and it may be an animal or a vegetable, or any natural object or phenomenon, or even a mere quality. The nature of totemism as a system is shown by the fact that among the Australians the totem is the symbol of a group of kinsmen. It is thus equivalent to a family name, and it is properly defined as a 'badge of fraternity,' answering to the 'device of a gens.' The gens was defined by Schoolcraft as the totemic institution, and a consideration of the rights and obligations of the gens throws light on the subject of totemism. The gens is founded on two chief conceptions, the bond of kin and non-intermarriage of persons belonging to the same gens. The former implies the obligation of mutual help, defence, and redress of injuries among the members of the gens. This obligation applies not only to human beings, but also to the totem group of objects, which are regarded as sacred by the members of the gens, although they may be killed and eaten by persons not belonging to it. These notions show a close connection of totemism with animal-worship and ancestor-worship. The conception of kinship is essential to ancestor-worship, which, like totemism, rests on the obligation of mutual aid and protection ; and this, again, is associated with the superstitious regard for certain animals and other objects, which are viewed by their human allies as guardian spirits.

The fundamental basis of totemism is to be found in the phase of human thought which supposes spirits 'to inhabit trees and groves, and to move in the winds and stars,' and which personifies almost every phase of nature. These notions were not unknown to the religious philosophy of antiquity, according to which the Universe or Great Cause was divided into two principles, that of light or good, answering to the active cause in nature ; and that of darkness or evil, answering to the passive cause ; each of which was subdivided into a multitude of partial causes, likewise intelligent. The idea of dualism in nature is found in Australian totemism, which is said to 'divide not mankind only, but the whole universe into what may almost be called gentile divisions.' It is connected also with the idea of transmigration, which was considered by ancient Oriental teaching as essential to the attainment of perfection by the human soul, the forms through which it was supposed to pass including not only beasts, birds, and fishes, but also trees, stones, and other inanimate objects. The problem of totemism receives its solution in the fact that the totem is the *re-incarnated form of the legendary ancestor of the gens or family group allied to the totem.* The totem is thus something more than a 'badge of fraternity' or 'device of a gens.' It is regarded as having actual vitality, as the embodiment of an ancestral spirit. Any object is fitted for this spirit re-incarnation, and therefore totemism may be looked upon as

[1] The paper has been published *in extenso* as chap. xii. of *Serpent-worship, and other Essays*, by the same author.

an expression of nature-worship and ancestor-worship in combination. The ancestral character of the totem accounts for the association with it of the idea of protection, which is based on the existence of a fraternal relationship between the totem and all the individuals belonging to a particular group of kin. The totem as a badge, device, or symbol thus represents the group of individuals, dead or alive, towards whom a man stands in a fraternal relation, and the protection of whom he is therefore entitled to, so long as he performs all the obligations on his part which flow from the existence of that relationship.

4. *Observations on Mr. Petrie's Ethnological Casts from Egypt.* *By* Dr. Isaac Taylor.

5. *Certain Degenerations of Design in Papuan Art.* *By* S. J. Hickson.

I. On a prau figure-head is a design which, although considerably modified, can readily be recognised as a design of the human figure: the long crimpled hair of the Papuan, two tufts of which are coloured red, in imitation of the red mud with which the Papuans complete their coiffure; the eyes, nose, and mouth of the face are clearly indicated, but the rest of the body is degenerated into a mere conventional sign.

On the prau side-boards and figure-heads from Merkhuis Island are similar designs, but the modification by degeneration has proceeded further, the features of the face by the appearance of an ornament in the middle of the forehead being considerably obscured. The two central tufts of hair, still coloured red, are drawn out considerably, as also are the lateral black tufts.

II. Upon the same prau figure-head, as in I., there is a figure of an animal (probably a gecko), fairly good and complete as a work of art, but upon the same is a design, evidently degenerated, of this in which all that remains unconventionalised is the anterior pair of legs.

Upon a house fetish in the author's possession this pair of legs appears, but the head and body of the animal is not represented even in conventional design.

Comparing this design with several in the Leyden museum still further degenerations may be noticed.

In two cases one of the legs has completely disappeared, in another one digit has disappeared, in another two, and in others the two legs become so blended that one would hardly recognise them as legs at all.

The designs are wrought by the old men or priests of the villages, and are made for the purpose of keeping off spirits of storm, thunder, sickness, &c.

Modifications are produced by the artist through want of time, ability, or inclination, and these modifications become permanent by being copied by subsequent artists, and thus in some cases mere conventional signs take the place of figures of men, birds, and other animals.

6. *On the Occurrence of Stone Mortars in the Ancient (Pliocene?) River-gravels of Butte Co., California.* *By* Sydney B. J. Skertchly, *F.G.S.*

Numerous stone objects, apparently ancient mortars, have been found during the working of auriferous gravels in California. It has been assumed that these gravels are of Pliocene age. The author recently visited the Spring Valley Gold Mine at Cherokee, Butte Co., California, where he obtained one of the mortars, which was exhibited. He concludes that the gravels may be of Glacial rather than Pliocene age. Their high antiquity is proved by the fact that they are overlain by a capping of lava, which has been cut through by the present rivers, and the gravels themselves worn down to a depth in some cases of 2,000 feet. They were, therefore, formed before the present drainage-system of the region was established.

7. *On Inscribed Stones from Mevagh and Barnes, Co. Donegal.* *By* G. H. Kinahan, *M.R.I.A.*

The author exhibited rubbings of several inscribed stones from Mevagh and Barnes, and read descriptive notes on their occurrence. The presence of crosses associated with certain circles was very notable. Several rubbings were exhibited from the inscribed monumental stones at Barnes. These standing stones are known as 'dallâns.'

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8. *Gipsies, and an Ancient Hebrew Race, in Sus and the Sahara.* *By* R. G. Haliburton.

Part I.

The province of Sus, as respects the customs of its people, is, and always has been, a *terra incognita.* Excepting a few lines by Herodotus, nothing has ever been written as to them, and this paper is the first attempt to describe them.

The Berbers of Morocco are divided into the Riffs and Susis; the first, light-haired and large men, living in the mountains; the latter, smaller, darker, and generally nomadic. The people of North Africa were called *Libu,* or *Ribu,* on the monuments, and hence the word *Libyan.* But the Riffs are called *Riffi,* or *Ribi*; hence, *Libyan* is the same as *Riffian.*

The Susis speak a dialect of Berber, called Shilhach, and are most of them gipsies of different descriptions. Some are skilful bellfounders, others make ornaments and arms, others saddlery, others dishes. Others are silver- and gold-smiths, and are famous for their skill as artificers. Most of them tell fortunes—some by sand, who are called *Amlad,* or *Remliien*; others by beads; others by a flower; some by watching a fowl after its head has been struck off; some by a shoulder-blade. The women in some tribes tell fortunes by the hand, and are called *Guessani,* or *De Guessan.* Some indulge in a sort of magic, and profess to call up spirits, or to make persons at a distance appear, using a powder on a fire which stupefies the inquirer. They also make charms for finding money, curing illness, calling back vagrant husbands, or for the production of olive branches, and for supplying all the wants of humanity.

These people have been for thousands of years, no doubt, connected with the Timbuctoo gold trade, and have picked up wandering habits, which have become hereditary.

They have secret signs and passes among themselves, called 'the words of the Kafila' (tent or lodge), which is probably the same word as the well-known 'Cabala' of the Jews.

It was shown that the Hyperboreans were the people to the south of the Atlas, or Riffian mountains (called in Greek mythology *Ripæan* mountains). There the prevailing N.E. wind is very pleasant in the winter, that place being beyond the rage of 'rude Boreas.' Beyond the Hyperboreans were, according to Herodotus, the 'one-eyed Arimaspians.' These, the writer contended, were the *Susis.* In proof of this he exhibited a bournous with an 'all-seeing eye' on the back, a yard in length. This ornament is peculiar to the Susis, and is like 'the eye of Osiris' and a well-known Masonic symbol. He showed that there are vestiges of the Osirian cult lingering among these people.

There is an ancient Jewish town near the Sahara, an entrepôt of the gold trade, called *Ophran,* on the river *Ophrar*; not far from it are the *Oulad bu Seba,* and farther south the *Oulad bu Saba,* or *Sabaeen.* The latter guide the caravans by the Seven Stars, and are, he contended, the old Sabæans, whose caravans wandered all over the ancient world. They are superior to the other tribes, and looked up to very much, as they know secret lore not known to others. Heeren conjectures that the gold trade of Africa must always have been in the hands of a religious guild.

A bracelet from the Sahara was exhibited, of horn, in the form of a serpent, with twelve divisions representing the months. In each division were two groups of seven stars, making twenty-four groups in all.

These gipsy tribes speak generally a language of their own, called in the west Zinagari, or Zingari, and to the south Zenagari. Leo Africanus calls it *Sungaï*. The Zenagar race (the old Getulian) extend beyond the *Senegal,* which owes its name to them. While there are many words in the European Zingari to be found in the Zinágari of the Sahara, there are very many words that are not common to them. A careful comparison of these languages by a philologist is very desirable.

Part II.

Ancient writers, referred to by Josephus, and an eminent authority, Tacitus, contend that Libya was the cradle of the Hebrew race. An old author, quoted by Josephus, describes a race that were in Western Ethiopia before the time of Abraham, the *Judadæans.* These were probably the Hebrews of Libya and the Sahara. They are different from what are known as the Barbary Jews, the descendants of fugitives from Spain and Portugal. They are rarely seen, living with the Riffs and Susis as their tradesmen and business men, and securing protection by a small annual payment. But there are independent tribes who own no master—some on the southern Atlas, some far east near the desert of Touareg, some, called Daggata, in the Sahara and as far south as the Niger. These tribes were described, one of which is protected by 'The Tomb of Our Beloved Lady'—that of the Jean of Arc of the Berbers, a Jewish woman, *Kahina,* who headed them against the Arabs and became their queen. The Arabs were compelled to make peace with her followers, and so great was her reputed sanctity, that the district around is a safe asylum for the Jews. Some of the Jews in the Sahara are black, with woolly hair; but most of the Berber Jews are very good-looking, and their women have the repute of being the most beautiful in the world. The Berber Jews look down on the coast Jews as schismatics, and are very rigid in their discipline, differing from the others in their dress and rites.

The writer showed that from a remote period there must have been in Libya a building which was claimed to be the Temple of Solomon. In Smith's 'Dictionary of the Bible' (*v.* 'Onias') is something on the subject of this temple. What has become of it since it fell into the hands of the Moslems is not known. The writer pointed out a singularly large number of the names of places in Sus which can be traced in Genesis, and suggested the inquiry, Has there been a migration of Hebrews from Palestine to Libya, or *vice versâ?*

The Jews and the gipsies must have been cast in the same mould, but must have been made of very different material. That mould, he believed, was the life in common in North Africa for thousands of years, in connection with the gold trade and the caravans of that country. They are Siamese twins, like, and yet, in some respects, utterly unlike, and equally unchangeable and distinct from the rest of mankind. We are almost tempted to call the gipsies 'the other peculiar people.'

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9. *Colour-names amongst the English Gipsies.*
By William E. A. Axon.

Considerable discussion has taken place as to the development of the colour-sense within the historic period. Mr. W. E. Gladstone's observations in 1858 as to the poverty of the Homeric colour-vocabulary were amplified by Geiger and Magnus. It is stated that blue, as an epithet applied to the sky, does not occur in the Old Testament, the Zend-Avesta, the Rig-Veda, the Homeric poems, or in the Koran. Mr. Gladstone in 1877 held that archaic man had a positive perception only of light and darkness, and that in the Homeric age he had advanced to the imperfect discrimination of red or yellow, but no further; green of grass and foliage or the blue of the sky being never once mentioned. The theory depends upon philological evidence, and the weak part of such an argument is that it may confuse mere poverty of nomenclature with defective perception. In several instances this danger has been shown to be real. As far back as the Stone Age there is evidence of the existence of the colour-sense.

The very basis of Geiger's theory is the exact conformity of the colour-sense and the colour-vocabulary. This theory may be tested by the facts as to the colour-names used by the English gipsies of to-day. Taking the learned monograph on 'The Dialect of the English Gipsies,' by Mr. B. C. Smart and Mr. H. T. Crofton, it is an easy matter to collect the words forming the scanty colour-vocabulary of the Anglo-Romanies. For 'gray' they use the word *bal, balaw*—hair, hairs. Thus the tribe-name of the Greys is the plural *Balaws,* and the same word is used for the Hernes, whose name is apparently connected with hair. The tribe of the Herrings are similarly styled *Balaw-Matchho*—'hair-fish,' apparently a punning translation of their English name. Gray, it may be remarked, when used in the Bible, is used in the sense of hoary and applied to hair. To express 'green' the Gipsies say *Chor-diking*—'grass-looking.' Sometimes they use *greeno* instead. Leland mentions also *selno.* The word for 'black' is *Kaúlo.* The word is applied also to common-heath from the waste lands of the Black Country and of Birmingham. The turkey is called *Kauli-rauni*—'black lady.' The word for 'red' is *lálo* or *lólo.* Cherries are *lálo-koóvau*—'red things.' The salmon is *lolo-matchho*—'red fish.' *Luller* is to 'blush.' The word for 'white' is *pórno,* which is also used for 'flour.' A swan is *pórni-rauni*—'white lady.' *Pórno-saster* is tin—'white iron.' When the words for 'sky,' 'morning,' &c., are examined, they are found not to have relation to colour. The sky is *dúvel*—'God,' or *miduvelesto-tem*—'God's country'; or *poodj*—a 'bridge.' 'Morning' is *Saúla*—the 'dawn.' The moon is *miduvelesko-dood*—'God's light'; or *Sikermeugro*—the 'showman.' Its common name is *shoon,* probably from the Sanscrit root *Tchadi*—to 'shine.' The sun is *kam,* from the Sanscrit root *gharma,* meaning 'heat.' It is also called *tam,* probably a corruption of *kam.* *Tamlo* means both 'light' and 'dark.' Amongst the Turkish gipsies *tam* means 'blind,' from the Sanskrit *tama*—'darkness.' The name of the 'orange,' *Pobomus,* is derived from *Pobo*—'apple.' The orange is sometimes called *Waver-temeski-lolo-pobo,* 'the-other-country-red-apple.'

The colour-vocabulary of the English gipsies is thus limited to 'green,' 'black,' 'red,' and 'white.' We have, then, the notable fact that 'blue,' on which so much stress has been laid in the discussion of the colour-sense, is entirely absent from the English gipsy vocabulary. This is emphasised by the fact that the gipsies sometimes use the word *blue-asar,* the suffix being that which is generally added in Romany to disguise a borrowed word. So their word for 'toadstools' is *blue-leggi,* because the *Agaricus personata,* which they regard as a delicacy, has blue stalks. Clearly if they had now in Romany a word for 'blue' they would not appropriate that of *Gaujo.* And if any evidence were needed that the Romanies are not colour-blind it is afforded by their appropriation of the English word for 'blue.' It only remains to add that *Yack* and *Erescare* are both given by Pott as gipsy equivalents for 'blue.' If these words are genuine—which may be open to doubt—it is apparently possible for a race to possess and to lose a colour-name. This brief investigation of the English gipsy colour-vocabulary will show the danger of accepting the negative testimony of philology as conclusive. The positive evidence of linguistics no one need doubt. It is clear that there is no relation between the colour-perception and the colour-nomenclature of the English gipsies.

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10. *The Seneca Indians of North America: their present Customs, Legends, and Language.* *By* John Wentworth Sanborn, *A.M.*

This paper opened with a description of the geographical location of the head-quarters of the Seneca Indian nation in the State of New York, where upwards of 3,000 of these strange people dwell.

Their religious ideas and practices were set forth.

The ceremony of the adoration of the maple and the green-corn dance, as witnessed by the author, and their annual New Year's Festivals, and the sacrifice of a white dog, as now practised by their pagan population, were described.

Curious facts concerning their domestic life, games, hospitality, &c., were presented.

Their peculiar modes of dress were treated of. Their unique methods of com-

puting time and measuring land were given, and their marriage customs and burial customs sketched.

The author described his adoption into the tribe, and inauguration as successor to the chief of the Wolf clan. He treated of their rich legendary lore, giving a short legend as related to him by the eldest man of the tribe, whom, together with all narrators or writers of fiction, the Indians call a 'great liar'—not in disrespect, however.

The language of the Senecas presents remarkable peculiarities, and these were pointed out. The language contains no labials, hence the Senecas know nothing of such letters as *b*, *f*, *l*, *m*, *p*, and *v*. Every letter in the language is sounded. There is not a noun of one syllable in the language.

There are three numbers, as in the Greek—viz., singular, dual, and plural. Pronouns are few. The word *iih* means *I*, *me*, *we*, and *us*. *Iis* means *thou*, *thee*, *you*, and *ye*.

The verb has an optative mood, like the Greek, and also an aorist tense. Adjectives abound in the language, and are generally compounded with the nouns which they are designed to qualify.

The numerals, as employed by the Senecas in everyday life, run up to about one hundred.

The paper closed with an account of the great Iroquois Confederation, which gave the North American continent to the English-speaking race.

11. *Contributions to the Remote History of Mankind.* *By* Akin Kàroly.

Although foreign to his avocations or pursuits, the question of the Turanian origin of the first founders of Babylon has from the first exercised considerable fascination on the mind of the writer. From fortuitous circumstances he has been led, within recent years, to identify various, hitherto believed distinct, terms of great importance in the history of religions; and, leisure permitting, he has within the last year or two followed up the same subject, into which he is now making assiduous researches.

The outcome of the latter has been, hitherto, the discovery of affinities or points of contact, heretofore unsuspected, between the religions of the more important races of the Aryan, Semitic, and Turanian sections of mankind, which will throw considerable light on the remote history of the civilised world.

A further result of these investigations, as yet, however, only begun, will be, more particularly, striking evidence of the great and unsurmised part enacted by the Turanian races in the history of the old world, comprising Asia, Africa, and Europe.

A final analysis of the subject-matters treated has, furthermore, revealed to the writer new views concerning the original formation of words, a question distinct, as he views it, from the origin of language.

The present paper forms a first instalment of these researches, and comprises the identification of several very important terms derived from what, for want of a better word, the writer would call the *theography* (denoting a means between *mythology* and *theology*) of ancient nations; added to which are new explanations of some geographical and ethnological terms also relating to the same.

TUESDAY, SEPTEMBER 6.

The following Report and Papers were read:—

1. *Report of the Committee for ascertaining and recording the localities in the British Islands in which evidences of the existence of Prehistoric Inhabitants of the country are found.*—See Reports, p. 168.

2. *On the Migrations of Pre-glacial Man.* *By* Henry Hicks, *M.D., F.R.S.*

Referring to the further researches carried on this summer at Cae-Gwyn Cave, North Wales, the author stated that the additional evidence obtained proved most conclusively that the flint implement found there last year in association with the remains of pleistocene animals was under entirely undisturbed glacial deposits. He maintained also that the evidence is equally clear in regard to the implements found within the caverns, which he said must have been introduced before the glacial deposits blocked up and covered over the caverns. The question as to the direction from which pre-glacial man reached this country is an exceedingly interesting one, and seems now to be fairly open to discussion. It is admittedly fraught with difficulties, but the facts recently obtained seem to require that an attempt should be made to unravel it. The evidence, so far as it goes, points to a migration to this country from some northern source, as the human relics found in the caverns, and also in the older river gravels (which Professor Prestwich is now disposed to assign also to the early part of the glacial epoch, when the ice-sheet was advancing), occur in association with the remains of animals of northern origin, such as the mammoth, rhinoceros, and reindeer. Up to the present time no human relics have been found in this country (and it is very doubtful whether they have been found in any other part of Europe) in deposits older than those containing the remains of these northern animals. If man arrived in this country from some eastern area it is but natural to think that he would have arrived when the genial pliocene climate tempted numerous species of deer of southern origin, and other animals suitable as food for man, to roam about in the south-east of England. Hitherto, however, not a relic has been found to show that man had arrived in this country at that time. But in the immediately succeeding period, with the advent of cold conditions and of the northern animals, evidences of the presence of man become abundant.

Whether man at an earlier period migrated northward from some tropical or sub-tropical area, and that he then lived on fruit and such-like food, there is no evidence at present to show; but it seems certain that the man of the glacial period in this country had to live mainly on animal food, and that he found the reindeer to be the most suitable to supply his wants. He followed the reindeer in their compulsory migrations during the gradually increasing glacial conditions, and kept mainly with them near the edge of the advancing ice.

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3. *The Early Neolithic Floor of East Lancashire.* *By* H. Colley March, *M.D.*

1. The extent and relative position of the floor.
2. The nature of the early neolithic material.
3. The source of this material.
4. The kinds and character of the implements.
5. Negative evidence from the floor.
6. Indications of antiquity.
7. General remarks and conclusions.

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4. *On recent Researches in Bench Cavern, Brixham, Devon.* *By* W. Pengelly, *F.R.S.*—See Section C, p. 710.

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5. *Observations on recent Explorations made by General Pitt-Rivers at Rushmore.* *By* J. G. Garson, *M.D., V.P.A.Inst.*

The author began his paper by defining the early British races. The earliest people of whom osteological remains are found were characterised by being of short stature and having long narrow heads and feebly-developed brow-ridges. Their

weapons were of stone, and they buried their dead very frequently in long barrows. It is generally accepted that the small dark people found in South Wales and other parts of the West of England to whom the name 'Iberian' is applied are the representatives of this early race. The country was next invaded by a tall race, with round heads and prominent brow-ridges, whose weapons were of bronze, and who interred their dead in round barrows. These are identified as the people against whom the Romans had to contend when they took possession of England, and who are known as the Kelts. Although many discoveries of the remains of these two races have been made at different times and in various parts of the country, much uncertainty still exists as to their history. During the last three years, and particularly during the past year, however, important information has been obtained regarding them from the discoveries of General Pitt-Rivers at Rushmore, near Salisbury, in the extreme south of Wiltshire. He has found on his estate there no less than four British villages of the Roman period, besides many other tumuli and cists. Two of these villages have now been excavated with the greatest care, and a very full description of the one first examined and of the several neighbouring tumuli has just been published in a handsome volume, containing no less than seventy-four quarto plates, and numerous woodcuts and tables. Both villages are situated on the Downs, on high ground, and were only marked, previous to their excavation, by slight elevations and depressions of the surface, which, on examination, proved to be the remains of what were once ditches and ramparts. Many parts of the village, however, showed no trace on the surface, and were only brought to light by carefully trenching nearly every foot of the ground within the ramparts. Very careful drawings have been made both of the villages and of all the other excavations, as well as of the objects found. The feature which particularly attracted the attention of everyone who saw these ancient villages after they had been excavated was the complicated system of ditches and pits they contained. The general plan of both villages is essentially the same. A main ditch and rampart situated internally to the former marks the external boundaries of each village, and numerous smaller ditches intersect the interior, all conducting in the direction of the watershed of the country. In the pits and in the ditches were found many human remains, several of which had been interred with the legs drawn up and the body resting on one or other side. Sometimes the interments were single, and in other cases two bodies were found together, with the heads in opposite directions. In most instances little care had been bestowed on the interments, and no rule had been followed in depositing the body. At different parts of the camp, and in the ditches and pits, were found considerable quantities of Roman pottery, coins, fibulæ, and various ornaments of bronze and iron, as well as worked stone implements. The village of Woodcuts, described in the work referred to, was particularly rich in these objects. In the interior of this village were found several wells, one of which was 188 feet in depth, and at the bottom of it was found the iron portions of a bucket. In the outskirts of the village were four hypocausts, or heating-places. Besides the human remains many remains of domestic animals, which proved to be those of *Bos longifrons*, a small long-legged variety of sheep, dogs of various sizes, pig, roe, red-deer, and horse were found. Also a considerable quantity of oyster-shells. Grains of wheat were found in one of the pits, associated with a bronze fibula and fragments of pottery. The human remains are extremely interesting, and throw much light on the characters of the people to whom they belonged. The chief point of interest which they show is the small stature of the people—the average height of the males being 5 feet 4 inches, and of the females 4 feet 11·8 inches, in the village of Woodcuts; and in that of Rotherly—the other village excavated this year—5 feet 1 inch and 4 feet 10 inches respectively. The skulls are of a long narrow oval form, with one or two exceptions, which are of rounder form. These latter were found associated with longer limb-bones, and evidently belonged to a different race from the majority of the inhabitants. Two types of skull are frequently met with in long barrows, both of a long narrow form, but differ from each other in one having a regular oval outline, while the other broadens out from a narrow forehead, and, having obtained its greatest width, terminates rapidly behind. The skulls found in the village correspond exactly to the first type. It

is therefore probable that there were two distinct races of the long-headed people, which will have to be distinguished in future.

The indications as to the history of the country derived from the discoveries of General Pitt-Rivers are, in the opinion of the author, that at one time the long-headed race inhabited the whole country; a race of round-headed people—the Kelts—came in from the East, and drove the long-headed persons westwards as far as the dense forests which covered the middle and west parts of England. These were in turn displaced and driven northwards and along the south coast, when the country was open, by the Roman invaders; hence the latter came in immediate contact with the older long-headed race.

6. *Note on the Ethnic Type of the Inhabitants of the Evolena Valley in Switzerland. By* Mrs. KNIGHT.

7. *On Berber and Guanche Tradition as to the Burial-place of Hercules. By* R. G. HALIBURTON.

As shown in a previous paper, the people of Mount Atlas still claim to be the oldest of nations, as they did in the time of Diodorus Siculus, who says that not only they, but also Greek mythologists believed that that country was 'the birth-place of all the gods of antiquity.' The oldest myths of Greece point to the West and to Mount Atlas; but in later times Mount Atlas and its myths were shifted to the north of the Danube, and even to Mount Caucasus.

The people to the south of Morocco, a very different race from those to the north, are nomadic, and given to necromancy and magic. They have a vast store of ancient traditions, and resemble the gipsies of Europe in their unchangeable characteristics.

It has been shown by French and other writers that the myth of Hercules and Geryon came from the Gauls and Kelts, and that it was borrowed by the Greeks and Romans from them. The Keltic Hercules is described fully in Smith's Dictionary of Greek and Roman Mythology. There is clear proof that the Northern nations of Europe derived these myths from the people of Mount Atlas, which was the scene of them. Hercules visits Atlas, and studies astronomy with him; resides among the Hyperboreans in Mount Atlas; makes the Straits of Gibraltar, and sets up the Pillars of Hercules. He sails west to the island of Erytheia, and steals the cows of Geryon; finds his way to the Eden of those daughters of Atlas, the Hesperides, or the 'Western ones,' and steals the famous golden apples.

It is interesting, therefore, to trace, if possible, local legends which connect him with that country. Ancient maps represent near Mogador 'the promontory of Hercules.' Why was it thus called? It is known only to the natives as 'the Mountain of Iron.'

I have heard tales of Hercules from many of the natives of Sus. A *Beni Bacchar*, or *Bes Carn* (the name of a tribe near *Massa*), said that 'Bacchar, or *Bibaween* (the drunken), made Ben Cantin's enemies drunk, and took them prisoners, and Ben Cantin lived forty years in the temple at Massa; but, in consequence of an outbreak, sailed away with all his treasures to the Mountain of Iron, and hid them there. Du Karnaiin, or Herge, a great freebooter, hearing of this, sailed there to find them, but without success. He then sailed to the Canaries in search of the 366 cows of Geryon, and went into a cave there, in which was a large dog with feet like those of a camel. The cave looked towards the sea, and was at the foot of a great mountain. He never came out, and the people closed the cave with stones.'

Another gave me a still more ancient tradition:—'Du Kernaiin, called Herklein, or Herkla, made the Straits of Gibraltar. In his time Sus and the Canaries were one country. He went to a large mountain in the Canaries to steal the 366 cows of Geryon, that came out always to pasture at sunset, and were watched by a dog named *Terras*. There was a great cave at the foot of the

mountain, called *Heber*, or *Kafoun Herge*. He went into the cave and was never seen again; and the cave was closed up with stones and lime, and cannot be found by men. There is a prophecy that when it is opened, the world will be changed.'

That time arrived a hundred years ago, when an earthquake exposed a vast mummy cave. At the far end of it is an opening in the face of a perpendicular cliff, which is hundreds of feet above the sea.

The Guanches must have had a similar tradition as to that cave, as it is called now (no one knows why) 'the cave of Herke.'

It is evident why Hercules remained in that cave. He went into it as a mummy.

How was it that this secret cave, closed ages ago, was known to the Susi, and even the fact that there was an opening in it that 'looked out towards the sea'?

It is difficult to suppose that this story is not a historical tradition. It must have been known to the Romans that Hercules sailed from the Mountain of Iron when they named it 'the promontory of Hercules'; and the Guanches must have heard that he was buried in a secret mummy cave in Teneriffe when they called it 'the cave of Herke.'

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[*An asterisk* (*) *signifies that no abstract of the communication is given.*]

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Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s.*

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our Knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and

recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Aryan and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn, on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lieut.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15*s.* (Out of Print.)

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840, to the 31st

of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16*s.* 6*d.*

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water, and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850, to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15*s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s.* 6*d.*

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—

William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —Dr. John P. Bell, Observations on the Character and Measurements of Degradation of the Yorkshire Coast;—First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration; —Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface; —W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s*.

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—

Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage, and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena, Part 1;—Dr. T. Wright, on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15*s.*

CONTENTS:—A. Cayley, Report on the recent progress of Theoretical Dynamics;—Sixteenth and Final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, de quelques Transformations de la Somme $\Sigma_{t_0}^{-a} \frac{a^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$ a étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $a^{t|+1}$ désignant le produit des facteurs $a\ (a+1)\ (a+2)$ &c.... $(a+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the Extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—Dr. John P. Hodges, on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Prof. W. A. Miller, on Electro-Chemistry;—John Simpson, Results of Thermometrical Observations made at the *Plover's* Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargreave, on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Prof. James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn, on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liver-

pool from the years 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, the Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20*s.*

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–1858;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connel and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857–58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles' Paper 'On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;'—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15*s.*

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to Cultivated Crops;—A. Thomson, of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahagow, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Brakes for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858–59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858–59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren De La Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The

Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air:—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Professor H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship Performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15*s*.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859–60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Prof. Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De La Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee;—Third Report of the Committee on Steamship Performance;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations;

—T. Dobson, on the Explosions in British Coal-Mines during the year 1859;—J. Oldham, Continuation of Report on Steam Navigation at Hull;—Prof. G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland;—Prof. Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind;—Colonel Sykes, Report of the Balloon Committee;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England;—Interim Report of the Committee for Dredging on the North and East Coasts of Scotland;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders;—Report of the Committee on the Law of Patents;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

Together with the Transactions of the Sections, Mr. Fairbairn's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SECOND MEETING at Cambridge, October 1862, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1861–62;—G. B. Airy, on the Strains in the Interior of Beams;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee;—Report on Tidal Observations on the Humber;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Donegal;—Prof. H. Hennessy, on the Vertical Movements of the Atmosphere considered in connection with Storms and Changes of Weather;—Report of Committee on the application of Gauss's General Theory of Terrestrial Magnetism to the Magnetic Variations;—Fleeming Jenkin, on Thermo-electric Currents in Circuits of one Metal;—W. Fairbairn, on the Mechanical Properties of Iron Projectiles at High Velocities;—A. Cayley, Report on the Progress of the Solution of certain Special Problems of Dynamics;—Prof. G. G. Stokes, Report on Double Refraction;—Fourth Report of the Committee on Steamship Performance;—G. J. Symons, on the Fall of Rain in the British Isles in 1860 and 1861;—J. Ball, on Thermometric Observations in the Alps;—J. G. Jeffreys, Report of the Committee for Dredging on the North and East Coasts of Scotland;—Report of the Committee on Technical and Scientific Evidence in Courts of Law;—James Glaisher, Account of Eight Balloon Ascents in 1862;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part IV.

Together with the Transactions of the Sections, the Rev. Prof. R. Willis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at* £1 5*s.*

CONTENTS:—Report of the Committee on the Application of Gun-cotton to Warlike Purposes;—A. Matthiessen, Report on the Chemical Nature of Alloys;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and on the Rocks associated with them;—J. G. Jeffreys, Report of the Committee appointed for exploring the Coasts of Shetland by means of the Dredge;—G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Aken, on the Transmutation of Spectral Rays, Part I.;—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods

used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Prof. Airy, Report on Steam Boiler Explosions;—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.;—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864, *Published at* 18*s*.

CONTENTS:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on Deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at* £1 5*s*.

CONTENTS:—J. G. Jeffreys, Report on Dredging among the Channel Isles;—F. Buckland, Report on the Cultivation of Oysters by Natural and Artificial Methods;—Report of the Committee for exploring Kent's Cavern;—Report of the Committee on Zoological Nomenclature;—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Interim Report on the Resistance of Water to Floating and Immersed Bodies;—Report on Observations of Luminous Meteors;—Report on Dredging on the Coast of Aberdeenshire;—J. Glaisher, Account of Three Balloon Ascents;—Interim Report on the Transmission of Sound under Water;—G. J. Symons, on the Rainfall of the British Isles;—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships;—Report of the Gun-Cotton Committee;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and Birmingham;—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds;—Report on further Researches in the Lingula-

flags of South Wales;—Report of the Lunar Committee for Mapping the Surface of the Moon;—Report on Standards of Electrical Resistance;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tifis;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part VI.;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science:—A. G. Findlay, on the Bed of the Ocean;—Prof. A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

Together with the Transactions of the Sections, Prof. Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at* £1 4*s*.

CONTENTS:—Second Report on Kent's Cavern, Devonshire;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron;—Report on Observations of Luminous Meteors;—W. S. Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies;—Dr. Norris, Report on Muscular Irritability;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the 'Menevian Group,' and the other Formations at St. David's, Pembrokeshire;—J. G. Jeffreys, Report on Dredging among the Hebrides;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II.;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides;—Report on Dredging in the Moray Firth;—Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee;—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J. Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands;—Report on the Penetration of Ironclad Ships by Steel Shot;—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

Together with the Transactions of the Sections, Mr. Grove's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at* £1 6*s*.

CONTENTS:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire;—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea;—Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis, in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Mechanical Properties of Steel;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Supplement to a Report on the Extinct Didine Birds of the Mascarene Islands;—Report on Observations of Luminous Meteors;—Fourth Report on Dredging among the Shetland Isles;—Preliminary Report on the Crustacea, &c., procured by the Shetland Dredging Committee in 1867;—Report on the Foraminifera obtained in the Shetland Seas;—Second Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at* £1 5*s.*

CONTENTS:—Report of the Lunar Committee;—Fourth Report on Kent's Cavern, Devonshire;—On Puddling Iron;—Fourth Report on the Structure and Classification of the Fossil Crustacea;—Report on British Fossil Corals;—Report on Spectroscopic Investigations of Animal Substances;—Report of Steamship Performance Committee;—Spectrum Analysis of the Heavenly Bodies;—On Stellar Spectrometry;—Report on the Physiological Action of the Methyl and allied Compounds;—Report on the Action of Mercury on the Biliary Secretion;—Last Report on Dredging among the Shetland Isles;—Reports on the Crustacea, &c., and on the Annelida and Foraminifera from the Shetland Dredgings;—Report on the Chemical Nature of Cast Iron, Part I.;—Interim Report on the Safety of Merchant Ships and their Passengers;—Report on Observations of Luminous Meteors;—Preliminary Report on Mineral Veins containing Organic Remains;—Report on the Desirability of Explorations between India and China;—Report of Rainfall Committee;—Report on Synthetical Researches on Organic Acids;—Report on Uniformity of Weights and Measures;—Report of the Committee on Tidal Observations;—Report of the Committee on Underground Temperature;—Changes of the Moon's Surface;—Report on Polyatomic Cyanides.

Together with the Transactions of the Sections, Dr. Hooker's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-NINTH MEETING, at Exeter, August 1869, *Published at* £1 2*s.*

CONTENTS:—Report on the Plant-beds of North Greenland;—Report on the existing knowledge on the Stability, Propulsion, and Seagoing qualities of Ships;—Report on Steam-boiler Explosions;—Preliminary Report on the Determination of the Gases existing in Solution in Well-waters;—The Pressure of Taxation on Real Property;—On the Chemical Reactions of Light discovered by Prof. Tyndall;—On Fossils obtained at Kiltorkan Quarry, co. Kilkenny;—Report of the Lunar Committee;—Report on the Chemical Nature of Cast Iron;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Report on the Practicability of establishing a 'Close Time' for the Protection of Indigenous Animals;—Experimental Researches on the Mechanical Properties of Steel;—Second Report on British Fossil Corals;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals for Photographing;—Report on the Rate of Increase of Underground Temperature;—Fifth Report on Kent's Cavern, Devonshire;—Report on the Connexion between Chemical Constitution and Physiological Action;—On Emission, Absorption, and Reflection of Obscure Heat;—Report on Observations of Luminous Meteors;—Report on Uniformity of Weights and Measures;—Report on the Treatment and Utilization of Sewage;—Supplement to Second Report of the Steamship-Performance Committee;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Mineral Veins in Carboniferous Limestone and their Organic Contents;—Notes on the Foraminifera of Mineral Veins and the Adjacent Strata;—Report of the Rainfall Committee;—Interim Report on the Laws of the Flow and Action of Water containing Solid Matter in Suspension;—Interim Report on Agricultural Machinery;—Report on the Physiological Action of Methyl and Allied Series;—On the Influence of Form considered in Relation to the Strength of Railway-axles and other portions of Machinery subjected to Rapid Alterations of Strain;—On the Penetration of Armour-plates with Long Shells of Large Capacity fired obliquely;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, Prof. Stokes's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTIETH MEETING, at Liverpool, September 1870, *Published at* 18*s.*

CONTENTS:—Report on Steam-boiler Explosions;—Report of the Committee on the Hæmatite Iron-ores of Great Britain and Ireland;—Report on the Sedimentary

Deposits of the River Onny;—Report on the Chemical Nature of Cast Iron;—Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals;—Report on Standards of Electrical Resistance;—Sixth Report on Kent's Cavern;—Third Report on Underground Temperature;—Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on the Stability, Propulsion, and Seagoing Qualities of Ships;—Report on Earthquakes in Scotland;—Report on the Treatment and Utilization of Sewage;—Report on Observations of Luminous Meteors, 1869–70;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On a new Steam-power Meter;—Report on the Action of the Methyl and Allied Series;—Report of the Rainfall Committee;—Report on the Heat generated in the Blood in the Process of Arterialization;—Report on the best means of providing for Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. Huxley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIRST MEETING, at Edinburgh, August 1871, *Published at* 16*s*.

CONTENTS:—Seventh Report on Kent's Cavern;—Fourth Report on Underground Temperature;—Report on Observations of Luminous Meteors, 1870–71;—Fifth Report on the Structure and Classification of the Fossil Crustacea;—Report of the Committee appointed for the purpose of urging on Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison;—Report of the Committee appointed for the purpose of Superintending the Publication of Abstracts of Chemical Papers;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Second Provisional Report on the Thermal Conductivity of Metals;—Report on the Rainfall of the British Isles;—Third Report on the British Fossil Corals;—Report on the Heat generated in the Blood during the Process of Arterialization;—Report of the Committee appointed to consider the subject of Physiological Experimentation;—Report on the Physiological Action of Organic Chemical Compounds;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on Steam-Boiler Explosions;—Report on the Treatment and Utilization of Sewage;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine;—Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals;—Report on Earthquakes in Scotland;—Report on the best means of providing for a Uniformity of Weights and Measures;—Report on Tidal Observations.

Together with the Transactions of the Sections, Sir William Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SECOND MEETING, at Brighton, August 1872, *Published at* £1 4*s*.

CONTENTS:—Report on the Gaussian Constants for the Year 1829;—Second Supplementary Report on the Extinct Birds of the Mascarene Islands;—Report of the Committee for Superintending the Monthly Reports of the Progress of Chemistry;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—Eighth Report on Kent's Cavern;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Fourth Report on the Fauna of South Devon;—Preliminary Report of the Committee appointed to Construct and Print Catalogues of Spectral Rays arranged upon a Scale of Wave-numbers;—Third Report on Steam-Boiler Explosions;—Report on Observations of Luminous Meteors, 1871–72;—Experiments on the Surface-friction experienced by a Plane moving through Water;—Report of the Committee on the Antagonism between the Action of Active Substances;—Fifth Report on Underground Temperature;—Preliminary Report of the Committee on Siemens's Electrical-Resistance Pyrometer;—Fourth Report on the Treatment and Utilization of Sewage;—Interim

Report of the Committee on Instruments for Measuring the Speed of Ships and Currents;—Report on the Rainfall of the British Isles;—Report of the Committee on a Geographical Exploration of the Country of Moab;—Sur l'élimination des Fonctions Arbitraires;—Report on the Discovery of Fossils in certain remote parts of the North-western Highlands;—Report of the Committee on Earthquakes in Scotland;—Fourth Report on Carboniferous-Limestone Corals;—Report of the Committee to consider the mode in which new Inventions and Claims for Reward in respect of adopted Inventions are examined and dealt with by the different Departments of Government;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Report on the Mollusca of Europe;—Report of the Committee for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report on the practicability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Sixth Report on the Structure and Classification of Fossil Crustacea;—Report of the Committee appointed to organize an Expedition for observing the Solar Eclipse of Dec. 12, 1871;—Preliminary Report of a Committee on Terato-embryological Inquiries;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On the Brighton Waterworks;—On Amsler's Planimeter.

Together with the Transactions of the Sections, Dr. Carpenter's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-THIRD MEETING, at Bradford, September 1873, *Published at £1 5s.*

CONTENTS:—Report of the Committee on Mathematical Tables;—Observations on the Application of Machinery to the Cutting of Coal in Mines;—Concluding Report on the Maltese Fossil Elephants;—Report of the Committee for ascertaining the Existence in different parts of the United Kingdom of any Erratic Blocks or Boulders;—Fourth Report on Earthquakes in Scotland;—Ninth Report on Kent's Cavern;—On the Flint and Chert Implements found in Kent's Cavern;—Report of the Committee for Investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report of Inquiry into the Method of making Gold-assays; —Fifth Report on the Selection and Nomenclature of Dynamical and Electrical Units;—Report of the Committee on the Labyrinthodonts of the Coal-measures;—Report of the Committee appointed to construct and print Catalogues of Spectral Rays;—Report of the Committee appointed to explore the Settle Caves;—Sixth Report on Underground Temperature;—Report on the Rainfall of the British Isles;—Seventh Report on Researches in Fossil Crustacea;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on the desirability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Report on Luminous Meteors; —On the Visibility of the Dark Side of Venus;—Report of the Committee for the Foundation of Zoological Stations in different parts of the World;—Second Report of the Committee for collecting Fossils from North-western Scotland;—Fifth Report on the Treatment and Utilization of Sewage;—Report of the Committee on Monthly Reports of the Progress of Chemistry;—On the Bradford Waterworks;—Report on the possibility of Improving the Methods of Instruction in Elementary Geometry; —Interim Report of the Committee on Instruments for Measuring the Speed of Ships, &c.;—Report of the Committee for Determinating High Temperatures by means of the Refrangibility of Light evolved by Fluid or Solid Substances;—On a Periodicity of Cyclones and Rainfall in connexion with Sun-spot Periodicity;—Fifth Report on the Structure of Carboniferous-Limestone Corals;—Report of the Committee on preparing and publishing brief forms of Instructions for Travellers, Ethnologists, &c.;—Preliminary Note from the Committee on the Influence of Forests on the Rainfall;—Report of the Sub-Wealden Exploration Committee;—Report of the Committee on Machinery for obtaining a Record of the Roughness of the Sea and Measurement of Waves near shore;—Report on Science Lectures and Organization;—Second Report on Science Lectures and Organization.

Together with the Transactions of the Sections, Prof. A. W. Williamson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FOURTH MEETING, at Belfast, August 1874, *Published at £1 5s.*

CONTENTS:—Tenth Report on Kent's Cavern;—Report for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Second Report of the Sub-Wealden Exploration Committee;—On the Recent Progress and Present State of Systematic Botany;—Report of the Committee for investigating the Nature of Intestinal Secretion;—Report of the Committee on the Teaching of Physics in Schools;—Preliminary Report for investigating Isomeric Cresols and their Derivatives;—Third Report of the Committee for collecting Fossils from localities in North-western Scotland;—Report on the Rainfall of the British Isles;—On the Belfast Harbour;—Report of Inquiry into the Method of making Gold-assays;—Report of a Committee on Experiments to determine the Thermal Conductivities of certain Rocks;—Second Report on the Exploration of the Settle Caves;—On the Industrial uses of the Upper Bann River;—Report of the Committee on the Structure and Classification of the Labyrinthodonts;—Second Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Sixth Report on the Treatment and Utilization of Sewage;—Report on the Anthropological Notes and Queries for the use of Travellers;—On Cyclone and Rainfall Periodicities;—Fifth Report on Earthquakes in Scotland;—Report of the Committee appointed to prepare and print Tables of Wave-numbers;—Report of the Committee for testing the new Pyrometer of Mr. Siemens;—Report to the Lords Commissioners of the Admiralty on Experiments for the Determination of the Frictional Resistance of Water on a Surface &c.;—Second Report for the Selection and Nomenclature of Dynamical and Electrical Units;—On Instruments for measuring the Speed of Ships;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee to inquire into the economic effects of Combinations of Labourers and Capitalists;—Preliminary Report on Dredging on the Coasts of Durham and North Yorkshire;—Report on Luminous Meteors;—Report on the best means of providing for a Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. John Tyndall's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIFTH MEETING, at Bristol, August 1875, *Published at £1 5s.*

CONTENTS:—Eleventh Report on Kent's Cavern;—Seventh Report on Underground Temperature;—Report on the Zoological Station at Naples;—Report of a Committee appointed to inquire into the Methods employed in the Estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea;—Second Report on the Thermal Conductivities of certain Rocks;—Preliminary Report of the Committee for extending the Observations on the Specific Volumes of Liquids;—Sixth Report on Earthquakes in Scotland;—Seventh Report on the Treatment and Utilization of Sewage;—Report of the Committee for furthering the Palestine Explorations;—Third Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Report of the Rainfall Committee;—Report of the Committee for investigating Isomeric Cresols and their Derivatives;—Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—On the Steering of Screw-Steamers;—Second Report of the Committee on Combinations of Capital and Labour;—Report on the Method of making Gold-assays;—Eighth Report on Underground Temperature;—Tides in the River Mersey;—Sixth Report of the Committee on the Structure of Carboniferous Corals;—Report of the Committee appointed to explore the Settle Caves;—On the River Avon (Bristol), its Drainage-Area, &c.;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee appointed to superintend the Publication of the Monthly Reports of the Progress of Chemistry;—Report on Dredging off the Coasts of Durham and North Yorkshire in 1874;—Report on Luminous Meteors;—On

the Analytical Forms called Trees;—Report of the Committee on Mathematical Tables;—Report of the Committee on Mathematical Notation and Printing;—Second Report of the Committee for investigating Intestinal Secretion;—Third Report of the Sub-Wealden Exploration Committee.

Together with the Transactions of the Sections, Sir John Hawkshaw's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SIXTH MEETING, at Glasgow, September 1876, *Published at £1 5s.*

CONTENTS:—Twelfth Report on Kent's Cavern;—Report on Improving the Methods of Instruction in Elementary Geometry;—Results of a Comparison of the British-Association Units of Electrical Resistance;—Third Report on the Thermal Conductivities of certain Rocks;—Report of the Committee on the practicability of adopting a Common Measure of Value in the Assessment of Direct Taxation;—Report of the Committee for testing experimentally Ohm's Law;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee on the Effect of Propellers on the Steering of Vessels;—On the Investigation of the Steering Qualities of Ships;—Seventh Report on Earthquakes in Scotland;—Report on the present state of our Knowledge of the Crustacea;—Second Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fourth Report of the Committee on the Erratic Blocks of England and Wales, &c.;—Fourth Report of the Committee on the Exploration of the Settle Caves (Victoria Cave);—Report on Observations of Luminous Meteors, 1875–76;—Report on the Rainfall of the British Isles, 1875–76;—Ninth Report on Underground Temperature;—Nitrous Oxide in the Gaseous and Liquid States;—Eighth Report on the Treatment and Utilization of Sewage;—Improved Investigations on the Flow of Water through Orifices, with Objections to the modes of treatment commonly adopted;—Report of the Anthropometric Committee;—On Cyclone and Rainfall Periodicities in connexion with the Sun-spot Periodicity;—Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee on Tidal Observations;—Third Report of the Committee on the Conditions of Intestinal Secretion and Movement;—Report of the Committee for collecting and suggesting subjects for Chemical Research.

Together with the Transactions of the Sections, Dr. T. Andrews's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SEVENTH MEETING, at Plymouth, August 1877, *Published at £1 4s.*

CONTENTS:—Thirteenth Report on Kent's Cavern;—Second and Third Reports on the Methods employed in the estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea (Part III.);—Third Report on the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fifth Report on the Erratic Blocks of England, Wales, and Ireland;—Fourth Report on the Thermal Conductivities of certain Rocks;—Report on Observations of Luminous Meteors, 1876–77;—Tenth Report on Underground Temperature;—Report on the Effect of Propellers on the Steering of Vessels;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on some Double Compounds of Nickel and Cobalt;—Fifth Report on the Exploration of the Settle Caves (Victoria Cave);—Report on the Datum Level of the Ordnance Survey of Great Britain;—Report on the Zoological Station at Naples;—Report of the Anthropometric Committee;—Report on the Conditions under which Liquid Carbonic Acid exists in Rocks and Minerals.

Together with the Transactions of the Sections, Prof. Allen Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-EIGHTH MEETING, at Dublin, August 1878, *Published at £1 4s.*

CONTENTS :—Catalogue of the Oscillation-Frequencies of Solar Rays ;—Report on Mr. Babbage's Analytical Machine ;—Third Report of the Committee for determining the Mechanical Equivalent of Heat ;—Report of the Committee for arranging for the taking of certain Observations in India, and Observations on Atmospheric Electricity at Madeira ;—Report on the commencement of Secular Experiments upon the Elasticity of Wires ;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Bebeerine ;—Report on the best means for the Development of Light from Coal-Gas ;—Fourteenth Report on Kent's Cavern ;—Report on the Fossils in the North-west Highlands of Scotland ;—Fifth Report on the Thermal Conductivities of certain Rocks ;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals ;—Report on the occupation of a Table at the Zoological Station at Naples ;—Report of the Anthropometric Committee ;—Report on Patent Legislation ;—Report on the Use of Steel for Structural Purposes ;—Report on the Geographical Distribution of the Chiroptera ;—Recent Improvements in the Port of Dublin ;—Report on Mathematical Tables ;—Eleventh Report on Underground Temperature ;—Report on the Exploration of the Fermanagh Caves ;—Sixth Report on the Erratic Blocks of England, Wales, and Ireland ;—Report on the present state of our Knowledge of the Crustacea (Part IV.) ;—Report on two Caves in the neighbourhood of Tenby ;—Report on the Stationary Tides in the English Channel and in the North Sea, &c. ;—Second Report on the Datum-level of the Ordnance Survey of Great Britain ;—Report on instruments for measuring the Speed of Ships ;—Report of Investigations into a Common Measure of Value in Direct Taxation ;—Report on Sunspots and Rainfall ; —Report on Observations of Luminous Meteors ;—Sixth Report on the Exploration of the Settle Caves (Victoria Cave) ;—Report on the Kentish Boring Exploration ;—Fourth Report on the Circulation of Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations, with an Appendix on the Filtration of Water through Triassic Sandstone ;—Report on the Effect of Propellers on the Steering of Vessels.

Together with the Transactions of the Sections, Mr. Spottiswoode's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-NINTH MEETING, at Sheffield, August 1879, *Published at £1 4s.*

CONTENTS :—Report on the commencement of Secular Experiments upon the Elasticity of Wires ;—Fourth Report of the Committee for determining the Mechanical Equivalent of Heat ;—Report of the Committee for endeavouring to procure reports on the Progress of the Chief Branches of Mathematics and Physics ;—Twelfth Report on Underground Temperature ;—Report on Mathematical Tables ;—Sixth Report on the Thermal Conductivities of certain Bocks ;—Report on Observations of Atmospheric Electricity at Madeira ;—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms ;—Report on the Calculation of Sun-Heat Coefficients ;—Second Report on the Stationary Tides in the English Channel and in the North Sea, &c. ;—Report on Observations of Luminous Meteors ;—Report on the question of Improvements in Astronomical Clocks ;—Report of the Committee for improving an Instrument for detecting the presence of Fire-damp in Mines ;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Beeberine ;—Seventh Report on the Erratic Blocks of England, Wales, and Ireland ;—Fifteenth Report on Kent's Cavern ;—Report on certain Caves in Borneo ;—Fifth Report on the Circulation of Underground Waters in the Jurassic, Red Sandstone, and Permian Formations of England ;—Report on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland ;—Report on the possibility of Establishing a 'Close Time' for the Protection of Indigenous Animals ;—Report on the Marine Zoology of Devon and Cornwall ;—Report on the Occupation of a Table at the Zoological Station at Naples ;—Report on Excavations at Portstewart and elsewhere in the North of Ireland ;—Report of the Anthropometric Committee ;—Report on the Investigation of the Natural History of Socotra ;—Report on Instru-

ments for measuring the Speed of Ships;—Third Report on the Datum-level of the Ordnance Survey of Great Britain;—Second Report on Patent Legislation;—On Self-acting Intermittent Siphons and the conditions which determine the commencement of their Action;—On some further Evidence as to the Range of the Palæozoic Rocks beneath the South-east of England;—Hydrography, Past and Present.

Together with the Transactions of the Sections, Prof. Allman's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTIETH MEETING, at Swansea, August and September 1880, *Published at* £1 4*s.*

CONTENTS:—Report on the Measurement of the Lunar Disturbance of Gravity;—Thirteenth Report on Underground Temperature;—Report of the Committee for devising and constructing an improved form of High Insulation Key for Electrometer Work;—Report on Mathematical Tables;—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms;—Report on Observations of Luminous Meteors;—Report on the question of Improvements in Astronomical Clocks;—Report on the commencement of Secular Experiments on the Elasticity of Wires;—Sixteenth and concluding Report on Kent's Cavern;—Report on the mode of reproduction of certain species of Ichthyosaurus from the Lias of England and Würtemburg;—Report on the Carboniferous Polyzoa;—Report on the 'Geological Record';—Sixth Report on the Circulation of the Underground Waters in the Permian, New Red Sandstone, and Jurassic Formations of England, and the Quantity and Character of the Water supplied to towns and districts from these formations;—Second Report on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland;—Eighth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on an Investigation for the purpose of fixing a Standard of White Light;—Report of the Anthropometric Committee;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen;—Second Report on the Marine Zoology of South Devon;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on accessions to our knowledge of the Chiroptera during the past two years (1878–80);—Preliminary Report on the accurate measurement of the specific inductive capacity of a good Sprengel Vacuum, and the specific resistance of gases at different pressures;—Comparison of Curves of the Declination Magnetographs at Kew, Stonyhurst, Coimbra, Lisbon, Vienna, and St. Petersburg;—First Report on the Caves of the South of Ireland;—Report on the Investigation of the Natural History of Socotra;—Report on the German and other systems of teaching the Deaf to speak;—Report of the Committee for considering whether it is important that H.M. Inspectors of Elementary Schools should be appointed with reference to their ability for examining in the scientific specific subjects of the Code in addition to other matters;—On the Anthracite Coal and Coalfield of South Wales;—Report on the present state of our knowledge of Crustacea (Part V.);—Report on the best means for the Development of Light from Coal-gas of different qualities (Part II.);—Report on Palæontological and Zoological Researches in Mexico;—Report on the possibility of establishing a 'Close Time' for Indigenous Animals;—Report on the present state of our knowledge of Spectrum Analysis;—Report on Patent Legislation;—Preliminary Report on the present Appropriation of Wages, &c.;—Report on the present state of knowledge of the application of Quadratures and Interpolation to Actual Data;—The French Deep-sea Exploration in the Bay of Biscay;—Third Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—List of Works on the Geology, Mineralogy, and Palæontology of Wales (to the end of 1873);—On the recent Revival in Trade.

Together with the Transactions of the Sections, Dr. A. C. Ramsay's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTY-FIRST MEETING, at York, August and September 1881, *Published at* £1 4*s.*

CONTENTS:—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms;—Report on Recent Progress in Hydrodynamics (Part I.);—Report on Meteoric Dust;—Second Report on the Calculation of Sun-heat Co-

efficients;—Fourteenth Report on Underground Temperature;—Report on the Measurement of the Lunar Disturbance of Gravity;—Second Report on an Investigation for the purpose of fixing a Standard of White Light;—Final Report on the Thermal Conductivities of certain Rocks;—Report on the manner in which Rudimentary Science should be taught, and how Examinations should be held therein, in Elementary Schools;—Third Report on the Tertiary Flora of the North of Ireland;—Report on the Method of Determining the Specific Refraction of Solids from their Solutions;—Fourth Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—Second Report on Fossil Polyzoa;—Report on the Maintenance of the Scottish Zoological Station;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on the Migration of Birds;—Report on the Natural History of Socotra;—Report on the Natural History of Timor-laut;--Report on the Marine Fauna of the Southern Coast of Devon and Cornwall;—Report on the Earthquake Phenomena of Japan;—Ninth Report on the Erratic Blocks of England, Wales, and Ireland;—Second Report on the Caves of the South of Ireland;—Report on Patent Legislation;—Report of the Anthropometric Committee;—Report on the Appropriation of Wages, &c.;—Report on Observations of Luminous Meteors;—Report on Mathematical Tables;—Seventh Report on the Circulation of Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quality and Quantity of the Water supplied to Towns and Districts from these Formations;—Report on the present state of our Knowledge of Spectrum Analysis;—Interim Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—On some new Theorems on Curves of Double Curvature;—Observations of Atmospheric Electricity at the Kew Observatory during 1880;—On the Arrestation of Infusorial Life by Solar Light;—On the Effects of Oceanic Currents upon Climates;—On Magnetic Disturbances and Earth Currents;—On some Applications of Electric Energy to Horticultural and Agricultural purposes;—On the Pressure of Wind upon a Fixed Plane Surface;—On the Island of Socotra;—On some of the Developments of Mechanical Engineering during the last Half-Century.

Together with the Transactions of the Sections, Sir John Lubbock's Address, and Recommendations of the Association and its Committees.

REPORT OF THE FIFTY-SECOND MEETING, at Southampton, August 1882, *Published at* £1 4*s*.

CONTENTS:—Report on the Calculation of Tables of Fundamental Invariants of Binary Quantics;—Report (provisional) of the Committee for co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861;—Report of the Committee appointed for fixing a Standard of White Light;—Report on Recent Progress in Hydrodynamics (Part II.);—Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—Fifteenth Report on Underground Temperature, with Summary of the Results contained in the Fifteen Reports of the Underground Temperature Committee;—Report on Meteoric Dust;—Second Report on the Measurement of the Lunar Disturbance of Gravity;—Report on the present state of our Knowledge of Spectrum Analysis;—Report on the Investigation by means of Photography of the Ultra-Violet Spark Spectra emitted by Metallic Elements, and their combinations under varying conditions;—Report of the Committee for preparing a new Series of Tables of Wave-lengths of the Spectra of the Elements;—Report on the Methods employed in the Calibration of Mercurial Thermometers;—Second Report on the Earthquake Phenomena of Japan;—Eighth Report on the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Water supplied to various Towns and Districts from these Formations;—Report on the Conditions under which ordinary Sedimentary Materials may be converted into Metamorphic Rocks;—Report on Explorations in Caves of Carboniferous Limestone in the South of Ireland;—Report on the Preparation of an International Geological Map of Europe;—Tenth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on Fossil Polyzoa (Jurassic Species—British Area only);—Preliminary Report on the Flora of the 'Halifax Hard Bed,' Lower Coal Measures;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen;—Report of the Committee appointed for obtaining Photographs of the Typical Races in the British Isles;—Preliminary Report on the Ancient Earthwork in Epping Forest known as the Loughton Camp;

—Second Report on the Natural History of Timor-laut;—Report of the Committee for carrying out the recommendations of the Anthropometric Committee of 1880, especially as regards the anthropometry of children and of females, and the more complete discussion of the collected facts;—Report on the Natural History of Socotra and the adjacent Highlands of Arabia and Somali Land;—Report on the Maintenance of the Scottish Zoological Station;—Report on the Migration of Birds;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on the Survey of Eastern Palestine;—Final Report on the Appropriation of Wages, &c.;—Report on the working of the revised New Code, and of other legislation affecting the teaching of Science in Elementary Schools;—Report on Patent Legislation;—Report of the Committee for determining a Gauge for the manufacture of various small Screws;—Report on the best means of ascertaining the Effective Wind Pressure to which buildings and structures are exposed;—On the Boiling Points and Vapour Tension of Mercury, of Sulphur, and of some Compounds of Carbon, determined by means of the Hydrogen Thermometer;—On the Method of Harmonic Analysis used in deducing the Numerical Values of the Tides of long period, and on a Misprint in the Tidal Report for 1872;—List of Works on the Geology and Palæontology of Oxfordshire, of Berkshire, and of Buckinghamshire;—Notes on the oldest Records of the Sea-Route to China from Western Asia;—The Deserts of Africa and Asia;—State of Crime in England, Scotland, and Ireland in 1880;—On the Treatment of Steel for the Construction of Ordnance, and other purposes;—The Channel Tunnel;—The Forth Bridge.

Together with the Transactions of the Sections, Dr. C. W. Siemens's Address, and Recommendations of the Association and its Committees.

REPORT OF THE FIFTY-THIRD MEETING, at Southport, September 1883, *Published at £1 4s.*

CONTENTS:—Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—Sixteenth Report on Underground Temperature;—Report on the best Experimental Methods that can be used in observing Total Solar Eclipses;—Report on the Harmonic Analysis of Tidal Observations;—Report of the Committee for co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861;—Report on Mathematical Tables;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Report on Meteoric Dust;—Report of the Committee appointed for fixing a Standard of White Light;—Report on Chemical Nomenclature;—Report on the investigation by means of Photography of the Ultra-Violet Spark Spectra emitted by Metallic Elements, and their combinations under varying conditions;—Report on Isomeric Naphthalene Derivatives;—Report on Explorations in Caves in the Carboniferous Limestone in the South of Ireland;—Report on the Exploration of Raygill Fissure, Yorkshire;—Eleventh Report on the Erratic Blocks of England, Wales, and Ireland;—Ninth Report on the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Water supplied to various Towns and Districts from these Formations;—Report on the Fossil Plants of Halifax;—Fourth Report on Fossil Polyzoa;—Fourth Report on the Tertiary Flora of the North of Ireland;—Report on the Earthquake Phenomena of Japan;—Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Third Report on the Natural History of Timor Laut;—Report on the Natural History of Socotra and the adjacent Highlands of Arabia and Somali Land;—Report on the Exploration of Kilima-njaro and the adjoining mountains of Eastern Equatorial Africa;—Report on the Migration of Birds;—Report on the Maintenance of the Scottish Zoological Station;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen;—Report on the Ancient Earthwork in Epping Forest, known as the 'Loughton' or 'Cowper's' Camp;—Final Report of the Anthropometric Committee;—Report of the Committee for defining the Facial Characteristics of the Races and Principal Crosses in the British Isles, and obtaining Illustrative Photographs;—Report on the Survey of Eastern Palestine;—Report on the workings of the proposed revised New Code, and of other legislation affecting the teaching of Science in Elementary Schools;—Report on Patent Legislation;—Report of the

Committee for determining a Gauge for the manufacture of various small Screws;—Report of the 'Local Scientific Societies' Committee;—On some results of photographing the Solar Corona without an Eclipse;—On Lamé's Differential Equation;—Recent Changes in the Distribution of Wealth in relation to the Incomes of the Labouring Classes;—On the Mersey Tunnel;—On Manganese Bronze;—Nest Gearing.

Together with the Transactions of the Sections, Professor Cayley's Address, and Recommendations of the Association and its Committees.

REPORT OF THE FIFTY-FOURTH MEETING, at Montreal, August and September, 1884, *Published at* 1*l*. 4*s*.

CONTENTS:—Report of the Committee for considering and advising on the best means for facilitating the adoption of the Metric System of Weights and Measures in Great Britain;—Report of the Committee for considering the best methods of recording the direct intensity of Solar Radiation;—Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—Report of the Committee for co-operating with the Meteorological Society of the Mauritius, in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861;—Second Report on the Harmonic Analysis of Tidal Observations;—Report of the Committee for co-operating with Mr. E. J. Lowe in his project of establishing a Meteorological Observatory near Chepstow on a permanent and scientific basis;—Report of the Committee for co-operating with the Directors of the Ben Nevis Observatory in making Meteorological Observations on Ben Nevis;—Report of the Committee for reducing and tabulating the Tidal Observations in the English Channel, made with the Dover Tide-gauge, and for connecting them with Observations made on the French Coast;—Fourth Report on Meteoric Dust;—Second Report on Chemical Nomenclature;—Report on Isomeric Naphthalene Derivatives;—Second Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Tenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Fifth and last Report on Fossil Polyzoa;—Twelfth Report on the Erratic Blocks of England, Wales, and Ireland;—Report upon the National Geological Surveys of Europe;—Report on the Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other material in that action;—Report on the Exploration of the Raygill Fissure in Lothersdale, Yorkshire;—Fourth Report on the Earthquake Phenomena of Japan;—Report on the occupation of a Table at the Zoological Station at Naples;—Fourth Report on the Natural History of Timor Laut;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen;—Report on the Migration of Birds;—Report on the Preparation of a Bibliography of certain groups of Invertebrata;—Report on the Exploration of Kilima-njaro, and the adjoining mountains of Eastern Equatorial Africa;—Report on the Survey of Eastern Palestine;—Report of the Committee for defraying the expenses of completing the Preparation of the final Report of the Anthropometric Committee;—Report on the teaching of Science in Elementary Schools;—Report of the Committee for determining a Gauge for the manufacture of the various small Screws used in Telegraphic and Electrical Apparatus, in Clockwork, and for other analogous purposes;—Report on Patent Legislation;—Report of the Committee for defining the Facial Characteristics of the Races and Principal Crosses in the British Isles, and obtaining Illustrative Photographs with a view to their publication;—Report on the present state of our knowledge of Spectrum Analysis;—Report of the Committee for preparing a new series of Wave-length Tables of the Spectra of the Elements;—On the Connection between Sun-spots and Terrestrial Phenomena;—On the Seat of the Electromotive Forces in the Voltaic Cell;—On the Archæan Rocks of Great Britain;—On the Concordance of the Mollusca inhabiting both sides of the North Atlantic and the intermediate Seas;—On the Characteristics of the North American Flora;—On the Theory of the Steam Engine;—Improvements in Coast Signals, with Supplementary Remarks on the New Eddystone Lighthouse;—On American Permanent Way.

Together with the Transactions of the Sections, Lord Rayleigh's Address, and Recommendations of the Association and its Committees.

REPORT OF THE FIFTY-FIFTH MEETING, at Aberdeen, September 1885, *Published at* £1 4*s*.

CONTENTS:—Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—Report of the Committee for promoting Tidal Observations in Canada;—Fifth Report on Meteoric Dust;—Third Report on the Harmonic Analysis of Tidal Observations;—Report of the Committee for co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861;—Report of the Committee for reducing and tabulating the Tidal Observations in the English Channel, made with the Dover Tide-gauge, and for connecting them with Observations made on the French Coast;—Report on Standards of White Light;—Report of the Committee for co-operating with Mr. E. J. Lowe in his project of establishing a Meteorological Observatory near Chepstow on a permanent and scientific basis;—Report on the best means of Comparing and Reducing Magnetic Observations;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Seventeenth Report on Underground Temperature;—Report on Electrical Theories;—Second Report of the Committee for considering the best methods of recording the direct intensity of Solar Radiation;—Report on Optical Theories;—Report of the Committee for investigating certain Physical Constants of Solution, especially the Expansion of Saline Solutions;—Third Report on Chemical Nomenclature;—Report of the Committee for the Investigation by means of Photography of the Ultra-Violet Spark Spectra emitted by Metallic Elements and their Combinations under varying conditions;—Report of the Committee for investigating the subject of Vapour Pressures and Refractive Indices of Salt Solutions;—Report of the Committee for preparing a new series of Wave-length Tables of the Spectra of the Elements and Compounds;—Thirteenth Report on the Erratic Blocks of England, Wales, and Ireland;—Third Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Fifth Report on the Earthquake Phenomena of Japan;—Eleventh Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Report on the Volcanic Phenomena of Vesuvius;—Report on the Fossil Plants of the Tertiary and Secondary Beds of the United Kingdom;—Report on the Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other material in that action;—Report on the occupation of a Table at the Zoological Station at Naples;—Report of the Committee for promoting the Establishment of a Marine Biological Station at Granton, Scotland;—Report on the Aid given by the Dominion Government and the Government of the United States to the Encouragement of Fisheries, and to the Investigation of the various forms of Marine Life on the coasts and rivers of North America;—Report of the Committee for promoting the Establishment of Marine Biological Stations on the coast of the United Kingdom;—Report on recent Polyzoa;—Third Report on the Exploration of Kilima-njaro and the adjoining mountains of Equatorial Africa;—Report on the Migration of Birds;—Report of the Committee for furthering the Exploration of New Guinea by making a grant to Mr. Forbes for the purposes of his Expedition;—Report of the Committee for furthering the Scientific Examination of the country in the vicinity of Mount Roraima in Guiana by making a grant to Mr. Everard F. im Thurn for the purposes of his Expedition;—Report of the Committee for promoting the Survey of Palestine;—Report on the Teaching of Science in Elementary Schools;—Report on Patent Legislation;—Report of the Committee for investigating and publishing reports on the physical characters, languages, and industrial and social condition of the North-Western Tribes of the Dominion of Canada;—Report of the Corresponding Societies Committee;—On Electrolysis;—A tabular statement of the dates at which, and the localities where Pumice or Volcanic Dust was seen in the Indian Ocean in 1883–4;—List of Works on the Geology, Mineralogy, and Palæontology of Staffordshire, Worcestershire, and Warwickshire;—On Slaty Cleavage and allied Rock-Structures, with special reference to the Mechanical Theories of their Origin;—On the Strength of Telegraph Poles;—On the Use of Index Numbers in the Investigation of Trade Statistics;—The Forth Bridge Works;—Electric Lighting at the Forth Bridge Works;—The New Tay Viaduct.

Together with the Transactions of the Sections, Sir Lyon Playfair's Address, and Recommendations of the Association and its Committees.

REPORT OF THE FIFTY-SIXTH MEETING, at Birmingham, September 1886, *Published at £1 4s.*

CONTENTS:—Report on Standards of Light;—Report of the Committee for preparing Instructions for the practical work of Tidal Observation, and Fourth Report on the Harmonic Analysis of Tidal Observations;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Third Report on the best methods of recording the Direct Intensity of Solar Radiation;—Second Report on the best means of Comparing and Reducing Magnetic Observations;—First Report on our Experimental Knowledge of the Properties of Matter with respect to Volume, Pressure, Temperature, and Specific Heat;—Third Report of the Committee for co-operating with Mr. E. J. Lowe in his project of establishing a Meteorological Observatory near Chepstow on a permanent and scientific basis;—Report of the Committee for inviting designs for a good Differential Gravity Meter in supersession of the Pendulum;—Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—Second Report of the Committee for promoting Tidal Observations in Canada;—Report of the Committee for the reduction and tabulation of Tidal Observations in the English Channel, made with the Dover Tide-gauge, and for connecting them with Observations made on the French Coast;—Report of the Committee for preparing a new series of Wave-length Tables of the Spectra of the Elements;—Second Report of the Committee for investigating the subject of Vapour Pressures and Refractive Indices of Salt Solutions;—Second Report of the Committee for investigating certain Physical Constants of Solution, especially the Expansion of Saline Solutions;—Report (provisional) on the influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Report on Isomeric Naphthalene Derivatives;—Report on the Exploration of the Caves of North Wales;—Fourteenth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Fourth Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Twelfth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Second Report on the Fossil Plants of the Tertiary and Secondary Beds of the United Kingdom;—Report on the Mechanism of the Secretion of Urine;—Report of the Committee for promoting the establishment of a Marine Biological Station at Granton, Scotland;—Report on the occupation of a Table at the Zoological Station at Naples;—Report on the Migration of Birds;—Report of the Committee for continuing the Researches on Food-Fishes and Invertebrates at the St. Andrews Marine Laboratory;—Report on the Depth of the Permanently Frozen Soil in the Polar Regions, its Geographical Limits and relation to the Pole of greatest cold;—Report of the Committee for taking into consideration the Combination of the Ordnance and Admiralty Surveys, and the Production of a Bathy-hypsographical Map of the British Isles;—Report of the Committee for drawing attention to the desirability of further Research in the Antarctic Regions;—Report on the teaching of Science in Elementary Schools;—Report on the Regulation of Wages by means of Sliding Scales;—Report on the Endurance of Metals under repeated and varying Stresses, and the proper working Stresses on Railway Bridges and other structures subject to varying loads;—Report on the Prehistoric Race in the Greek Islands;—Report of the Committee for investigating and publishing reports on the physical characters, languages, and industrial and social condition of the North-western Tribes of the Dominion of Canada;—Report to the Council of the Corresponding Societies Committee;—Report on Electrolysis in its Physical and Chemical Bearings;—Sixth Report on the Volcanic Phenomena of Japan;—Second Report on the Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other Material in that action;—The Modern Development of Thomas Young's Theory of Colour-vision;—On the Explicit Form of the Complete Cubic Differential Resolvent;—On the Phenomena and Theories of Solution;—On the Exploration of the Raygill Fissure in Lothersdale, Yorkshire;—An Accurate and Rapid Method of estimating the Silica in an Igneous Rock:—On some Points for the Consideration of English Engineers with reference to the Design of Girder Bridges;—The Sphere and Roller Mechanism for Transmitting Power;—On Improvements in Electric Safety Lamps;—On the Birmingham, Tame, and Rea District Drainage.

Together with the Transactions of the Sections, Sir J. William Dawson's Address, and Recommendations of the Association and its Committees.

BRITISH ASSOCIATION

FOR

THE ADVANCEMENT OF SCIENCE.

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OF

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CORRECTED TO JANUARY 21, 1888.

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THISELTON-DYER, W. T., Esq., C.M.G., F.R.S.
THORPE, Professor T. E., F.R.S.
WOODWARD, Dr. H., F.R.S.

GENERAL SECRETARIES.

Capt. Sir DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.G.S., 12 Chester Street, London, S.W.
A. G. VERNON HARCOURT, Esq., M.A., LL.D., F.R.S., F.C.S., Cowley Grange, Oxford.

SECRETARY.

ARTHUR T. ATCHISON, Esq., M.A., 22 Albemarle Street, London, W.

GENERAL TREASURER.

Professor A. W. WILLIAMSON, Ph.D., LL.D., F.R.S., F.C.S., University College, London, W.C.

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Sir JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S.
The Right Hon. Lord RAYLEIGH, M.A., D.C.L., LL.D., Sec. R.S., F.R.A.S.
The Right Hon. Sir LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S.

PRESIDENTS OF FORMER YEARS.

The Duke of Devonshire, K.G.
Sir G. B. Airy, K.C.B., F.R.S.
The Duke of Argyll, K.G., K.T.
Sir Richard Owen, K.C.B., F.R.S.
Lord Armstrong, C.B., LL.D.
Sir William R. Grove, F.R.S.
Sir Joseph D. Hooker, K.C.S.I.
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Prof. Sir Wm. Thomson, LL.D.
Prof. Williamson, Ph.D., F.R.S.
Prof. Tyndall, D.C.L., F.R.S.
Sir John Hawkshaw, F.R.S.
Prof. Allman, M.D., F.R.S.
Sir A. C. Ramsay, LL.D., F.R.S.
Sir John Lubbock, Bart., F.R.S.
Prof. Cayley, LL.D., F.R.S.
Lord Rayleigh, D.C.L., Sec. R.S.
Sir Lyon Playfair, K.C.B.
Sir Wm. Dawson, C.M.G., F.R.S.

GENERAL OFFICERS OF FORMER YEARS.

F. Galton, Esq., F.R.S.
Dr. T. A. Hirst, F.R.S.
Dr. Michael Foster, Sec. R.S.
George Griffith, Esq., M.A., F.C.S.
P. L. Sclater, Esq., Ph.D., F.R.S.
Prof. Bonney, D.Sc., F.R.S.

AUDITORS.

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LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1887.

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* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Secretary, 22 Albemarle Street, London, W.

Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough House, Burgess Hill, Sussex.
1887. *Abbe, Cleveland. Weather Bureau, Army Signal Office, Washington, U.S.A.
1881. *Abbott, R. T. G. Quarry Cottage, Norton, Malton.
1887. §Abbott, T. C. Eastleigh, Queen's-road, Bowdon, Cheshire.
1863. *ABEL, Sir FREDERICK AUGUSTUS, C.B., D.C.L., F.R.S., F.C.S., Director of the Chemical Establishment of the War Department. Royal Arsenal, Woolwich.
1856. ‡Abercrombie, John, M.D. 39 Welbeck-street, London, W.
1886. §Abercromby, The Hon. Ralph, F.R.Met.Soc. 21 Chapel-street, Belgrave-square, London, S.W.
1885. *ABERDEEN, The Right Hon. the Earl of, LL.D. 37 Grosvenor-square, London, W.
1885. ‡Aberdeen, The Countess of. 37 Grosvenor-square, London, W.
1885. ‡Abernethy, David W. Ferryhill Cottage, Aberdeen.
1863. *ABERNETHY, JAMES, M.Inst.C.E., F.R.S.E. 4 Delahay-street, Westminster, S.W.
1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.
1873. *ABNEY, Captain W. DE W., R.E., F.R.S., F.R.A.S., F.C.S. Willeslie House, Wetherby-road, South Kensington, London, S.W.

Year of
Election.

1886. §Abraham, Harry. 147 High-street, Southampton.
1877. ‡Ace, Rev. Daniel, D.D., F.R.A.S. Laughton, near Gainsborough, Lincolnshire.
1884. ‡Achison, George. Collegiate Institute, Toronto, Canada.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1882. *Acland, Alfred Dyke. Oxford.
1869. ‡Acland, Charles T. D., M.P. Sprydoncote, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. School of Gunnery, Shoeburyness.
1873. *Acland, Rev. H. D., M.A. Nymet St. George, South Molton, Devon.
1873. *ACLAND, Sir HENRY W. D., K.C.B., M.A., M.D., LL.D., F.R.S., F.R.G.S., Radcliffe Librarian and Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
1877. *Acland, Theodore Dyke, M.A. 7 Brook-street, London, W.
1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.
1887. §ADAMI, J. G., B.A. New Museums, Cambridge.
1884. ‡Adams, Frank Donovan. Geological Survey, Ottawa, Canada.
1876. ‡Adams, James. 9 Royal-crescent West, Glasgow.
*ADAMS, JOHN COUCH, M.A., LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1871. §Adams, John R. 3 Queen's-gate-terrace, London, S.W.
1879. *ADAMS, Rev. THOMAS, M.A., Principal of Bishop's College, Lennoxville, Canada.
1877. ‡ADAMS, WILLIAM. 3 Sussex-terrace, Plymouth.
1869. *ADAMS, WILLIAM GRYLLS, M.A., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Notting Hill-square, London, W.
1873. ‡*Adams-Acton, John. Margutta House, 103 Marylebone-road, London, N.W.*
1887. §Adamson, Daniel, The Towers, Didsbury, Manchester.
1879. ‡Adamson, Robert, M.A., LL.D., Professor of Logic and Political Economy in Owens College, Manchester. 1 Derby-road, Fallowfield, Manchester.
1887. §Adamson, Samuel A., F.G.S. 52 Wellclose-terrace, Leeds.
1865. *Adkins, Henry. Northfield, near Birmingham.
1883. §Adshead, Samuel. School of Science, Macclesfield.
1884. ‡Agnew, Cornelius R. 266 Maddison-avenue, New York, U.S.A.
1887. §Agnew, William. Summer Hill, Pendleton, Manchester.
1884. ‡Aikins, Dr. W. T. Jarvis-street, Toronto, Canada.
1864. *Ainsworth, David. The Flosh, Cleator, Carnforth.
1871. *Ainsworth, John Stirling. Harecroft, Cumberland.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
AIRY, Sir GEORGE BIDDELL, K.C.B., M.A., LL.D., D.C.L., F.R.S., F.R.A.S. The White House, Croom's Hill, Greenwich, S.E.
1871. §Aitken, John, F.R.S.E. Darroch, Falkirk, N.B.
Aitken, Thomas, Ashfield, Fallowfield, Manchester.
Akroyd, Edward. Bankfield, Halifax.
1884. *Alabaster, H. 22 Paternoster-row, London, E.C.
1886. *Albright, G. S. The Elms, Edgbaston, Birmingham.
1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.
1861. *Alcock, Thomas, M.D. Oakfield, Sale, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.

Year of Election.

1887. §Alexander, B. Fernlea, Fallowfield, Manchester.
1883. ‡Alexander, George. Kildare-street Club, Dublin.
1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.
1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.
1883. ‡Alger, Miss Ethel. Widey Court, near Plymouth.
1883. §Alger, W. H. Widey Court, near Plymouth.
1883. ‡Alger, Mrs. W. H. Widey Court, near Plymouth.
1867. ‡Alison, George L. C. Dundee.
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1885. ‡Allan, David. West Cults, near Aberdeen.
1871. ‡Allan, G., M.Inst.C.E. 10 Austin Friars, London, E.C.
1871. §ALLEN, ALFRED H., F.C.S. 67 Surrey-street, Sheffield.
1887. *Allen, Arthur Ackland. Overbrook, Kersal, Manchester.
1879. *Allen, Rev. A. J. C. The College, Chester.
1887. *Allen, Charles Peter. Overbrook, Kersal, Manchester.
1884. §Allen, Rev. George. Shaw Vicarage, Oldham.
1887. §Allen, John. Kilgrimol School, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.
1861. ‡Allen, Richard. Didsbury, near Manchester.
1887. *Allen, Russell. 2 Parkwood, Victoria Park, Manchester.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*ALLMAN, GEORGE J., M.D., LL.D., F.R.S. L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmore, Parkstone, Dorset.
1887. *Allnutt, J. W. F., B.A. 12 Chapel-row, Portsea, Hants.
1886. ‡Allport, Samuel. 50 Whitall-street, Birmingham.
1887. §Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1883. §Amery, John Sparke. Druid House, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid House, Ashburton, Devon.
1884. ‡Ami, Henry. Geological Survey, Ottawa, Canada.
1876. ‡Anderson, Alexander. 1 St. James's-place, Hillhead, Glasgow.
1878. ‡Anderson, Beresford. Saint Ville, Killiney.
1885. ‡Anderson, Charles Clinton. 4 Knaresborough-place, Cromwell-road, London, S.W.
1850. ‡Anderson, Charles William. Cleadon, South Shields.
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1885. *Anderson, Hugh Kerr. Frognal Park, Hampstead, London, N.W.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1859. ‡ANDERSON, PATRICK. 15 King-street, Dundee.
1887. §Anderson, Professor R. J., M.D. Queen's College, Galway.
1880. *ANDERSON, TEMPEST, M.D., B.Sc. 17 Stonegate, York.
1886. *Anderson, William, M.Inst.C.E. Lesney House, Erith, Kent.
1880. ‡Andrew, Mrs. 126 Jamaica-street, Stepney, London, E.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William. Gosford Green, Coventry.
1883. §Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §ANGELL, JOHN, F.C.S. The Grammar School, Manchester.
1886. §Annan, John. Wolverhampton.
1886. ‡Ansell, Joseph. 38 Waterloo-street, Birmingham.
1878. ‡Anson, Frederick H. 9 Delahay-street, Westminster, S.W.
Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.
1868. ‡*Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.*
1886. §Arblaster, Edmund, M.A. The Grammar School, Carlisle.

Year of Election.

1884. ‡Archbold, George. Oswego, New York, U.S.A.
1870. ‡Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1874. ‡Archer, William, F.R.S., M.R.I.A. 11 South Frederick-street, Dublin.
1884. *Archibald, E. Douglas. Grosvenor House, Tunbridge Wells.
1851. ‡ARGYLL, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inverary, Argyleshire.
1884. §Arlidge, John Thomas, M.D., B.A. The High Grove, Stoke-upon-Trent.
1883. §Armistead, Richard. Wharncliffe House, Beaufort-road, Brooklands, near Manchester.
1883. *Armistead, William. 15 Rupert-street, Compton-road, Wolverhampton.
1887. §Armitage, Benjamin. Chomlea, Pendleton, Manchester.
1861. ‡Armitage, William. 95 Portland-street, Manchester.
1867. *Armitstead, George. Errol Park, Errol, N.B.
1857. *ARMSTRONG, The Right Hon. Lord, C.B., LL.D., D.C.L., F.R.S. Jesmond Dene, Newcastle-upon-Tyne.
1879. *Armstrong, Sir Alexander, K.C.B., M.D., LL.D., F.R.S., F.R.G.S. The Albany, London, W.
1886. §Armstrong, George Frederick, M.A., F.R.S.E., F.G.S., Regius Professor of Engineering in the University of Edinburgh. The University, Edinburgh.
1873. §ARMSTRONG, HENRY E., Ph.D., F.R.S., Sec.C.S., Professor of Chemistry in the City and Guilds of London Institute Central Institution, Exhibition-road, London, S.W. 55 Granville Park, Lewisham, S.E.
1876. ‡Armstrong, James. Bay Ridge, Long Island, New York, U.S.A.
1884. ‡Armstrong, Robert B. Junior Carlton Club, Pall Mall, London, S.W.
Armstrong, Thomas. Higher Broughton, Manchester.
1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.
1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1886. ‡Ascough, Jesse. Patent Borax Company, Newmarket-street, Birmingham.
1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1884. *Asher, Asher, M.D. 18 Endsleigh-street, Tavistock-square, London, W.C.
1873. ‡Ashton, John. Gorse Bank House, Windsor-road, Oldham.
ASHTON, THOMAS, J.P. Ford Bank, Didsbury, Manchester.
1887. §Ashton, Thomas Gair, M.A. 36 Charlotte-street, Manchester.
1866. ‡Ashwell, Henry. Woodthorpe, Nottingham.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
1887. §Ashworth, Mrs. Harriet. Thorne Bank, Heaton Moor, near Stockport.
Ashworth, Henry. Turton, near Bolton.
1887. §Ashworth, John Wallwork. Thorne Bank, Heaton Moor, near Stockport.
1887. §Aspland, Arthur P. Werneth Lodge, Gee Cross, near Manchester.
1875. *Aspland, W. Gaskell. Care of Manager, Union Bank, Chancery-lane, London, W.C.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, London, W.C.
1872. *ATCHISON, ARTHUR T., M.A. (SECRETARY.) 22 Albemarle-street, London, W.

Year of
Election.

1858. ‡*Atherton, Charles. Sandover, Isle of Wight.*
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1884. ‡Atkinson, Edward. Brookline, Massachusetts, Boston, U.S.A.
1863. *Atkinson, G. Clayton. 21 Windsor-terrace, Newcastle-on-Tyne.
1887. §Atkinson, Rev. G. C. Goresfield, Ashton-on-Mersey.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, John Hastings. 12 East Parade, Leeds.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. ‡Atkinson, Robert William. Town Hall-buildings, Newcastle-on-Tyne.
1863. *ATTFIELD, Professor J., M.A., Ph.D., F.R.S., F.C.S. 17 Bloomsbury-square, London, W.C.
1884. ‡Auchincloss, W. S. 209 Church-street, Philadelphia, U.S.A.
1886. §Aulton, A. D., M.D. Walsall.
1860. *Austin-Gourlay, Rev. William E. C., M.A. The Rectory, Stanton St. John, near Oxford.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1881. ‡AXON, W. E. A. Fern Bank, Higher Broughton, Manchester.
1877. *AYRTON, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Institute Central Institution, Exhibition-road, London, S.W.

*BABINGTON, CHARLES CARDALE, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
1884. ‡Baby, The Hon. G. Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's Wolsingham, near Darlington.
1887. *Bacon, Thomas Walter. 4 Lyndhurst-road, Hampstead, London, N.W.
1887. §Baddeley, John. 1 Charlotte-street, Manchester.
1881. ‡Baden-Powell, Sir George S., C.M.G., M.A., M.P., F.R.A.S., F.S.S. 8 St. George's-place, Hyde Park, London, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. ‡Bagrual, P. H. St. Stephen's Club, Westminster, S.W.
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1870. §Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Owens College, Manchester.
1878. ‡Bailey, John. The Laurels, Wittington, near Hereford.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1887. §Bailey, W. H. Summerfield, Eccles Old-road, Manchester.
1866. ‡Baillon, Andrew. British Consulate, Brest.
1878. ‡Baily, Walter. 176 Haverstock-hill, London, N.W.
1857. ‡BAILY, WILLIAM HELLIER, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street, Dublin.
1885. ‡BAIN, ALEXANDER, M.A., LL.D., Rector of the University of Aberdeen. Ferryhill Lodge, Aberdeen.
1873. ‡Bain, Sir James. 3 Park-terrace, Glasgow.
1885. §Bain, William N. Collingwood, Pollockshiels, Glasgow.
*Bainbridge, Robert Walton. 2 Stoke-villas, Exeter.
*BAINES, Sir EDWARD, J.P. Belgrave-mansions, Grosvenor-gardens, London, S.W.; and St. Ann's Hill, Burley, Leeds.

Year of Election.

1858. ‡*Baines Frederick. Burley, near Leeds.*
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1882. *BAKER, BENJAMIN, M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1866. ‡Baker, Francis B. Sherwood-street, Nottingham.
1886. §Baker, Harry. 262 Plymouth-grove, Manchester.
1861. *Baker, John. The Gables, Buxton.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1865. ‡Baker, Robert L. Barham House, Leamington.
1863. ‡Baker, William. 6 Taptonville, Sheffield.
1875. *Baker, W. Mills. The Holmes, Stoke Bishop, Bristol.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. ‡BALFOUR, ISAAC BAYLEY, D.Sc., M.D., F.R.S.L. & E., Professor of Botany in the University of Oxford. Fairacres, Oxford.
1883. ‡Balfour, Mrs. I. Bayley. Fairacres, Oxford.
1878. *Ball, Charles Bent, M.D. 16 Lower Fitzwilliam-street, Dublin.
1835. *BALL, JOHN, M.A., F.R.S., F.L.S., M.R.I.A. 10 Southwell-gardens, South Kensington, London, S.W.
1866. *BALL, Sir ROBERT STAWELL, M.A., LL.D., F.R.S., F.R.A.S., Andrews Professor of Astronomy in the University of Dublin, and Astronomer Royal for Ireland. The Observatory, Dunsink, Co. Dublin.
1878. ‡BALL, VALENTINE, M.A., F.R.S., F.G.S., Director of the Museum of Science and Art, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. §Ballantyne, J. W., M.B. 50 Queen-street, Edinburgh.
1884. ‡Ballon, Dr. Naham. Sandwich, Illinois, U.S.A.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1882. ‡Bance, Major Edward. Limewood, The Avenue, Southampton.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1879. ‡*Banham, H. French. Mount View, Glossop-road, Sheffield.*
1870. ‡BANISTER, Rev. WILLIAM, B.A. St. James's Mount, Liverpool.
1884. ‡Bannatyne, Hon. A. G. Winnipeg, Canada.
1884. ‡Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. ‡Barber, Rev. S. F. West Raynham Rectory, Swaffham, Norfolk.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1859. ‡Barbour, George F. 11 George-square, Edinburgh.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1887. *Barclay, Robert. Springfield, Kersal, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. G. Above Bar, Southampton.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1886. ‡Barham, F. F. Bank of England, Birmingham.

Year of Election.

1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1879. ‡Barker, Elliott. 2 High-street, Sheffield.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. North Petherton, Bridgwater.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡Barkly, Sir Henry, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Binagardens, South Kensington, London, S.W.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
1885. ‡Barlow, William. Hillfield, Muswell Hill, London, N.
1873. ‡Barlow, William Henry, F.R.S., M.Inst.C.E. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. Harlow, Essex.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1884. §Barnett, J. D. Port Hope, Ontario, Canada.
1886. ‡Barnsley, Charles H. 32 Duchess-road, Edgbaston, Birmingham.
1881. ‡Barr, Archibald, B.Sc., Professor of Civil and Mechanical Engineering in the Yorkshire College, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1883. ‡Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1860. ‡Barrett, T. B. 20 Victoria-terrace, Welshpool, Montgomery.
1872. *Barrett, W. F., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Winton Lodge, Crosby, near Liverpool.
1887. §Barrington, Miss Amy. Centre School, West Grove, Darlington.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1885. *Barron, Frederick Cadogan, M.Inst.C.E. Nervion, Beckenham-grove, Shortlands, Kent.
1881. §Barron, G. B., M.D. Summerseat, Southport.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1886. §Barrow, George William. Baldraud, Lancaster.
1887. §Barrow, John. Beechfield, Folly-lane, Swinton, Manchester.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ompton-road, Edgbaston, Birmingham.
1886. ‡Barrows, Joseph. The Poplars, Yardley, near Birmingham.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.
1862. *Barry, Charles. 15 Pembridge-square, London, W.
1883. ‡Barry, Charles E. 15 Pembridge-square, London, W.
1875. ‡Barry, John Wolfe. 23 Delahay-street, Westminster, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances. Garrow Hill, near York.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.

Year of
Election.

1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, George C. T., M.P. St. Margaret's House, Victoria-street, London, S.W.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1887. §Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1882. *BASING, The Right Hon. Lord, F.R.S. 74 St. George's-square, London, S.W.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1866. *BASSETT, HENRY. 26 Belitha-villas, Barnsbury, London, N.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.D., M.A., F.R.S., F.L.S. 20 Queen Anne-street, London, W.
1848. ‡BATE, C. SPENCE, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1883. ‡Bateman, A. E. Board of Trade, London, S.W.
1873. *Bateman, Daniel. Wissahickon, Philadelphia, U.S.A.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
BATEMAN, JAMES, M.A., F.R.S., F.R.G.S., F.L.S. Home House, Worthing.
1842. *BATEMAN, JOHN FREDERIC LA TROBE, F.R.S., F.G.S., F.R.G.S., M.Inst.C.E. 16 Great George-street, London, S.W.
1864. ‡BATES, HENRY WALTER, F.R.S., F.L.S., Assist.-Sec. R.G.S. 1 Savile-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1884. ‡Bateson, William, B.A. St. John's College, Cambridge.
1851. ‡BATH AND WELLS, The Right Rev. Lord ARTHUR HERVEY, Lord Bishop of, D.D. The Palace, Wells, Somerset.
1881. *Bather, Francis Arthur, M.A., F.G.S. 20 Campden Hill-road, Kensington, London, W.
1836. ‡Batten, Edmund Chisholm. 25 Thurloe-square, London, S.W.
1869. ‡*Batten, John Winterbotham. 35 Palace Gardens-terrace, Kensington, London, W.*
1863. §BAUERMAN, H., F.G.S. 41 Acre-lane, Brixton, London, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, The Right Hon. William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *BAYNES, ROBERT E., M.A. 14 Bradmore-road, Oxford.
1887. *Baynes, Mrs. R. E. 14 Bradmore-road, Oxford.
1887. §Baynton, Alfred. 28 Gilda Brook Park, Eccles, Manchester.
1883. *Bazley, Gardner. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Hatherop Castle, Fairford, Gloucestershire.
1886. §Beale, C. Lime Tree House, Rowley Regis, Dudley.
1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *BEALE, LIONEL S., M.D., F.R.S., Professor of the Principles and Practice of Medicine in King's College, London. 61 Grosvenor-street, London, W.
1882. §Beamish, Major A. W., R.E. 28 Grosvenor-road, London, S.W.
1884. ‡Beamish, G. H. M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.

Year of Election.

1870. ‡Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
1883. ‡Beard, Mrs. 13 South-hill-road, Toxteth Park, Liverpool.
1887. §Beaton, John, M.A. 219 Upper Brook-street, Chorlton-on-Medlock, Manchester.
1842. *Beatson, William. Ash Mount, Rotherham.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, London, W.
1886. ‡Beaugrand, M. H. Montreal.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1887. *Beaumont, W. J. Angel Hotel, Knutsford.
1885. §Beaumont, W. W. 163 Strand, London, W.C.
1871. *Beazley, Lieut.-Colonel George G. 74 Redcliffe-square, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 68 Cornhill, London, E.C.
1864. §Becker, Miss Lydia E. 155 Shrewsbury-street, Whalley Range, Manchester.
1887. *Beckett, John Hampden. Wilmslow Park, Wilmslow, Manchester.
1860. ‡BECKLES, SAMUEL H., F.R.S., F.G.S. 9 Grand-parade, St. Leonard's-on-Sea.
1885. §BEDDARD, FRANK E., M.A., F.Z.S., Prosector to the Zoological Society of London. Society's Gardens, Regent's Park, London, N.W.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §BEDDOE, JOHN, M.D., F.R.S. Clifton, Bristol.
1858. ‡Bedford, James. Woodhouse Cliff, near Leeds.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S., Professor of Chemistry in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1873. ‡Bell, Asahel P. 32 St. Anne's-street, Manchester.
1871. §Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1880. ‡Bell, Henry Oswin. 13 Northumberland-terrace, Tynemouth.
1862. *BELL, Sir ISAAC LOWTHIAN, Bart., F.R.S., F.C.S., M.Inst.C.E. Rounton Grange, Northallerton.
1875. ‡Bell, James, Ph.D., F.R.S., F.C.S. The Laboratory, Somerset House, London, W.C.
1871. *BELL, J. CARTER, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. Dalton Lees, Huddersfield.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. ‡Bell, R. Bruce, M.Inst.C.E. 203 St. Vincent-street, Glasgow.
1863. *Bell, Thomas. Oakwood, Epping.
1867. ‡Bell, Thomas. Belmont, Dundee.
1882. ‡*Bell, W. Alexander, B.A. 3 Madeira-terrace, Kemp Town, Brighton.*
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1882. ‡Bellingham, William. 15 Killieser-avenue, Telford Park, Streatham Hill, London, S.W.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden. 7 Exchange-street, Manchester.

Year of Election.

1885. §BENHAM, WILLIAM BLAXLAND, D.Sc. 34 Belsize-road, London, N.W.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1836. §Bennett, Henry. Bedminster, Bristol.
1887. §Bennett, James M. St. Mungo Chemical Company, Ruckhill, Glasgow.
1881. §Bennett, John R. 16 West Park, Clifton, Bristol.
1883. *Bennett, Laurence Henry. Bedminster, Bristol.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishophill Junior, York.
1870. *Bennett, William. Heysham Tower, Lancaster.
1870. *Bennett, William. Oak Hill Park, Old Swan, near Liverpool.
1887. §Bennion, James A., M.A. 1 St. James'-square, Manchester.
1852. *Bennoch, Francis, F.S.A. 5 Tavistock-square, London, W.C.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1885. *Bent, J. Theodore. 13 Great Cumberland-place, London, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada
1842. *Bentley John. 2 Portland-place, London, W.*
1863. ‡BENTLEY, ROBERT, F.L.S., Professor of Botany in King's College, London. 38 Penywern-road, Earl's Court, London, S.W.
1886. ‡Benton, William Elijah. Littleworth House, Hednaford, Staffordshire.
1876. ‡Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.
1868. ‡BERKELEY, Rev. M. J., M.A., F.R.S., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. L. 1 New-court, Lincoln's Inn, London, W.C.
1887. §Berry, William. Harpurhey Cottage, Harpurhey, Manchester.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1865. *BESSEMER, Sir HENRY, F.R.S. Denmark Hill, London, S.E.
1882. *Bessemer, Henry, jun. 5 Palace-gate, Kensington, London, W.
1858. ‡Best, William. Leydon-terrace, Leeds.
1883. ‡Betley, Ralph, F.G.S. Mining School, Wigan.
1876. *Bettany, G. T., M.A., B.Sc., F.L.S., F.R.M.S. 33 Oakhurst-grove, East Dulwich-road, London, S.E.
1883. ‡Bettany, Mrs. 33 Oakhurst-grove, East Dulwich-road, London, S.E.
1880. *Bevan, Rev. James Oliver, M.A., F.G.S. The Vicarage, Vowchurch, Hereford.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1884. *Beverley, Michael, M.D. 52 St. Giles'-street, Norwich.
1874. *Bevington, James B. Merle Wood, Sevenoaks.
1863. ‡Bewick, Thomas John, F.G.S. Suffolk House, Laurence Pountney Hill, London, E.C.
1844. *Bickerdike, Rev. John, M.A. Shireshead Vicarage, Garstang.
1886. §Bickersteth, The Very Rev. E., D.D., Dean of Lichfield. The Deanery, Lichfield.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1885. *BIDWELL, SHELFORD, M.A., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1882. §Biggs, C. H. W., F.C.S. 1 Bloomfield, Bromley, Kent.
1864. ‡Biggs, Robert. 16 Green Park, Bath.

Year of Election.

Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.
1886. §Bindloss, G. F. Carnforth, Brondesbury Park, London, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, John E. Electric Works, Sheffield.
1881. ‡Binnie, Alexander R., F.G.S. Town Hall, Bradford, Yorkshire.
1879. ‡Binns, E. Knowles, F.R.G.S. 216 Heavygate-road, Sheffield.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1880. ‡Bird, Henry, F.C.S. South Down, near Devonport.
1866. *Birkin, Richard. Aspley Hall, near Nottingham.
1887. *Birley, H. K. 13 Hyde-road, Ardwick, Manchester.
1871. *Bischof, Gustav. 4 Hart-street, Bloomsbury, London, W.C.
1868. ‡*Bishop, John. Thorpe Hamlet, Norwich.*
1883. §Bishop, John le Marchant. 100 Mosley-street, Manchester.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Captain W. H. War Department, Washington, U.S.A.
1877. ‡Blachford, The Right Hon. Lord, K.C.M.G. Cornwood, Ivybridge.
1884. ‡Black, Francis, F.R.G.S. 6 North Bridge, Edinburgh.
1881. §Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. Calverley Park, Tunbridge Wells.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John Stewart, M.A., Professor of Greek in the University of Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace, Glasgow.
1855. *Blackie, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1884. ‡Blaikie, James, M.A. 14 Viewforth-place, Edinburgh.
1878. §Blair, Matthew. Oakshaw, Paisley.
1883. §Blair, Mrs. Oakshaw, Paisley.
1863. ‡Blake, C. Carter, D.Sc. 27 Hastings-street, Burton-crescent, London, W.C.
1886. ‡Blake, Dr. James. San Francisco, California.
1849. *Blake, Henry Wollaston, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1883. *Blake, Rev. J. F., M.A., F.G.S., Professor of Natural Science in University College, Nottingham.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1878. ‡Blakeney, Rev. Canon, M.A., D.D. The Vicarage, Sheffield.
1886. ‡Blakie, John. The Bridge House, Newcastle, Staffordshire.
1861. §Blakiston, Matthew, F.R.G.S. Free Hills, Burledon, Hants.
1887. §Blamires, George. Cleckheaton.
1881. §Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1884. *Blandy, William Charles, B.A. 1 Friar-street, Reading.
1869. ‡Blanford, W. T., LL.D., F.R.S., Sec. G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, London, W.
1887. *Bles, A. G. S. Moor End, Kersal, Manchester.
1887. *Bles, Edward J. Moor End, Kersal, Manchester.
1887. §Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.

Year of Election.

1869. *BLOMEFIELD, Rev. LEONARD, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1880. §Bloxam, G. W., M.A., F.L.S. 11 Chalcot-crescent, Regent's Park, London, N.W.
1883. ‡Blumberg, Dr. 65 Hoghton-street, Southport.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Captain Richard. Bretlands, Chertsey, Surrey.
1885. §BLYTH, JAMES, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
Blyth, B. Hall. 135 George-street, Edinburgh.
1883. ‡Blyth, Miss Phœbe. 3 South Mansion House-road, Edinburgh.
1887. §Blythe, William S. 65 Mosley-street, Manchester.
1867. ‡Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1871. ‡Bohn, Mrs. North End House, Twickenham.
1887. *Boissevain, Gideon Maria. 4 Jesselschade-straat, Amsterdam.
1881. ‡Bojanowski, Dr. Victor de. 27 Finsbury-circus, London, E.C.
1876. ‡Bolton, J. C. Carbrook, Stirling.
Bond, Henry John Hayes, M.D. Cambridge.
1883. §Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, London, N.W.
1871. *BONNEY, Rev. THOMAS GEORGE, D.Sc., LL.D., F.R.S., F.S.A., F.G.S., Professor of Geology in University College, London. 23 Denning-road, Hampstead, London, N.W.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. ‡Booth, James. Elmfield, Rochdale.
1883. §Booth, James. Hazelhurst House, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, London, W.C.
1876. ‡Booth, Rev. William H. St. Germain's-place, Blackheath, London, S.E.
1883. ‡Boothroyd, Benjamin. Rawlinson-road, Southport.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. ‡Borns, Henry, Ph.D., F.C.S. Friedheim, Springfield-road, Wimbledon, Surrey.
1876. *Bosanquet, R. H. M., M.A., F.C.S., F.R.A.S. St. John's College, Oxford.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §Bothamley, Charles H. Yorkshire College, Leeds.
1867. §Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1887. §Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. §Bottomley, Dr. John. 220 Lower Broughton-road, Manchester.
1871. *BOTTOMLEY, JAMES THOMSON, M.A., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
Bottomley, William. 11 Delamere-street, London, W.
1876. ‡Bottomley, William, jun. 6 Rokeley-terrace, Hillhead, Glasgow.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1883. §Bourdas, Isaiah. 59 Belgrave-road, London, S.W.

Year of Election.

1883. ‡BOURNE, A. G., D.Sc., F.L.S., Professor of Zoology in the Presidency College, Madras.
1866. §BOURNE, STEPHEN, F.S.S. Abberley, Wallington, Surrey.
1884. §BOVEY, HENRY T., M.A., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1870. ‡Bower, Anthony. Bowersdale, Seaforth, Liverpool.
1881. *BOWER, F. O., F.L.S., Professor of Botany in the University of Glasgow.
1867. ‡Bower, Dr. John. Perth.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1886. ‡Bowlby, Rev. Canon. 101 Newhall-street, Birmingham.
1884. ‡Bowley, Edwin. Burnt Ash Hill, Lee, Kent.
1880. ‡Bowly, Christopher. Cirencester.
1887. §Bowly, Mrs. Christopher. Cirencester.
1865. §Bowman, F. H., D.Sc., F.R.S.E. Halifax, Yorkshire.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
BOWMAN, Sir WILLIAM, Bart., M.D., LL.D., F.R.S., F.R.C.S. 5 Clifford-street, London, W.
1869. ‡Bowring, Charles T. Elmsleigh, Prince's-park, Liverpool.
1887. §Box, Alfred M. Scissett, near Huddersfield.
1863. ‡Boyd, Edward Fenwick. Moor House, near Durham.
1884. *Boyd, M. A., M.D. 30 Merrion-square, Dublin.
1887. §Boyd, Robert. Manor House, Didsbury, Manchester.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, The Very Rev. G. D., M.A., Dean of Salisbury. The Deanery, Salisbury.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.
1872. *BRABROOK, E. W., F.S.A. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1884. *Brace, W. H., M.D. 7 Queen's Gate-terrace, London, S.W.
1880. ‡Bradford, H. Stretton House, Walters-road, Swansea.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
1863. ‡BRADY, GEORGE S., M.D., F.R.S., F.L.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1862. ‡BRADY, HENRY BOWMAN, F.R.S., F.L.S., F.G.S. 5 Robert-street, Adelphi, London, W.C.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, Romford, Essex, E.
1864. §BRAHAM, PHILIP, F.C.S. Bath.
1870. ‡Braidwood, Dr. 35 Park-road South, Birkenhead.
1879. ‡Bramley, Herbert. Claremont-crescent, Sheffield.
1865. §BRAMWELL, Sir FREDERICK J., D.C.L., F.R.S., M.Inst.C.E. (PRESIDENT ELECT). 5 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. Dickleburgh Rectory, Scole, Norfolk.
1885. *Bratby, W. Pott-street, Ancoats, Manchester.
1852. ‡BRAZIER, JAMES S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1882. *Bretherton, C. E. 1 Garden-court, Temple, London, E.C.
1881. *Brett, Alfred Thomas, M.D. Watford House, Watford.

Year of Election.

1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. ‡Briant, T. Hampton Wick, Kingston-on-Thames.
1886. §Bridge, T. W., M.A., Professor of Zoology in the Mason Science College, Birmingham.
1884. ‡Bridges, C. J. Winnipeg, Canada.
1870. *Bridson, Joseph R. Sawrey, Windermere.
1887. §Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *Brigg, John. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.
1863. *Bright, Sir Charles Tilston, M.Inst.C.E., F.G.S., F.R.G.S., F.R.A.S. 20 Bolton-gardens, London, S.W.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
Bright, The Right Hon. John, M.P. Rochdale, Lancashire.
1868. ‡Brine, Captain Lindesay, F.R.G.S. United Service Club, Pall Mall, London, S.W.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1879. ‡Brittain, Frederick. Taptonville-crescent, Sheffield.
1879. *Brittain, W. H. Storth Oaks, Ranmoor, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, London, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. Farad Villa, Vanbrugh Hill, Blackheath, London, S.E.
1859. *Brodhurst, Bernard Edward, F.R.C.S., F.L.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1883. *Brodie, David, M.D. Care of J. G. Johnson, Esq., Southwood-court, Highgate, London, N.
1865. ‡Brodie, Rev. Peter Bellinger, M.A., F.G.S. Rowington Vicarage, near Warwick.
1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1878. *Brook, George, F.L.S. The University, Edinburgh.
1880. ‡Brook, G. B. Brynsyfi, Swansea.
1881. §Brook, Robert G. Rowen-street, St. Helen's, Lancashire.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. Canon J. Ingham. Thornhill Rectory, Dewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1878. ‡Brooke, Sir Victor, Bart., F.L.S. Colebrook, Brookeborough, Co. Fermanagh.
1887. §Brooks, James Howard. Green Bank, Monton, Eccles, Manchester.
1863. ‡Brooks, John Crosse. 14 Lorain-place, Newcastle-on-Tyne.
1887. §Brooks, S. H. Slade House, Levenshulme, Manchester.
1846. *Brooks, Thomas. Cranshaw Hall, Rawtenstall, Manchester.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1887. *Bros, W. Law. Sidcup, Kent.
1883. §Brotherton, E. A. Fern Cliffe, Ilkley, Leeds.
1886. §Brough, Joseph. University College, Aberystwith.
1885. *Browett, Alfred. 14 Dean-street, Birmingham.
1863. *Brown, Alexander Crum, M.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. 93 Abbey-hill, Edinburgh.

Year of Election.

1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. §Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1887. §Brown, George. Cadishead, near Manchester.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1884. ‡Brown, Gerald Culmer. Lachute, Quebec, Canada.
1883. ‡Brown, Mrs. H. Bienz. 26 Ferryhill-place, Aberdeen.
1884. §Brown, Harry. University College, London, W.C.
1883. ‡Brown, Mrs. Helen. 52 Grange Loan, Edinburgh.
1870. §BROWN, HORACE T. 47 High-street, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1883. ‡Brown, Miss Isabella Spring. 52 Grange Loan, Edinburgh.
1870. *BROWN, Professor J. CAMPBELL, D.Sc., F.C.S. University College, Liverpool.
1876. ‡Brown, John. Edenderry House, Belfast.
1881. *Brown, John, M.D. 68 Bank-parade, Burnley, Lancashire.
1882. *Brown, John. Swiss Cottage, Park-valley, Nottingham.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Haddington, N.B.
1874. ‡Brown, John S. Edenderry, Shaw's Bridge, Belfast.
1882. *Brown, Mrs. Mary. 68 Bank-parade, Burnley, Lancashire.
1885. ‡*Brown Miss. Springfield House, Ilkley, Yorkshire.*
1886. §Brown R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. ‡BROWN, ROBERT, M.A., Ph.D., F.L.S., F.R.G.S. Fersley, Rydal-road, Streatham, London, S.W.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41A New-street, Birmingham.
1885. ‡Brown, W. A. The Court House, Aberdeen.
1884. ‡Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1879. ‡Browne, J. Crichton, M.D., LL.D., F.R.S. L. & E. 7 Cumberland-terrace, Regent's Park, London, N.W.
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1865. *Browne, William, M.D. Heath Wood, Leighton Buzzard.
1887. §Brownell, T. W. 6 St. James's-square, Manchester.
1865. ‡Browning, John, F.R.A.S. 63 Strand, London, W.C.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1863. *Brunel, H. M. 23 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.
1875. *BRUNLEES, Sir JAMES, F.R.S.E., F.G.S., M.Inst.C.E. 5 Victoria-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1868. ‡BRUNTON, T. LAUDER, M.D., D.Sc., F.R.S. 50 Welbeck-street, London, W.
1878. §Brutton, Joseph. Yeovil.
1886. *Bryan, G. H. Trumpington-road, Cambridge.
1877. ‡*Bryant George. 82 Claverton-street, Pimlico, London, S.W.*
1884. ‡Bryce, Rev. Professor George. The College, Manitoba, Canada.
BRYCE, Rev. R. J., LL.D. Fitzroy-avenue, Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S.E., Sec. Scottish Meteorological Society. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.

Year of Election.

1885. *Buchan, William Paton. Fairyknowe, Cambuslang, N.B.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. 12 Barnard-road, Birkenhead, Cheshire.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, F.R.S. 10 Moray-place, Edinburgh.
1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. §Buckland, Miss A. W. 54 Doughty-street, London, W.C.
1886. *Buckle, Edmund W. 23 Bedford-row, London, W.C.
1864. §BUCKLE, Rev. GEORGE, M.A. The Rectory, Weston-super-Mare.
1865. *Buckley, Henry. 27 Wheeley's-road, Edgbaston, Birmingham.
1886. §Buckley, Samuel. 76 Clyde-road, Albert-park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. Science and Art Department, South Kensington, London, S.W.
1880. §Buckney, Thomas, F.R.A.S. Delhi House, Coventry Park, Streatham, S.W.
1869. ‡Bucknill, J. C., M.D., F.R.S. E 2 Albany, London, W.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1887. §Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. §Budgett, Samuel. Cotham House, Bristol.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1871. ‡Bulloch, Matthew. 4 Bothwell-street, Glasgow.
1881. ‡Bulmer, T. P. Mount-villas, York.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1865. ‡Bunce, John Mackray. 'Journal' Office, New-street, Birmingham.
1863. ‡Bunning, T. Wood. Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
1886. §Burbury, S. H. 1 New-square, Lincoln's Inn, London, W.C.
1842. *Burd, John. 5 Gower-street, London, W.C.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, London, W.
1881. ‡Burdett-Coutts, W. L. A. B., M.P. 1 Stratton-street, Piccadilly, London, W.
1884. *Burland, Jeffrey H. 287 University-street, Montreal, Canada.
1883. *Burne, Colonel Sir Owen Tudor, K.C.S.I., C.I.E., F.R.G.S. 57 Sutherland-gardens, Maida Vale, London, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. 123½ Union-street, Aberdeen.
1877. ‡Burns, David. Alston, Carlisle.
1884. §Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1883. ‡Burr, Percy J. 20 Little Britain, London, E.C.
1881. §Burroughs, S. M. Snow Hill-buildings, London, E.C.
1883. *Burrows, Abraham. Greenhall, Atherton, near Manchester.
1887. §Burrows, Eggleston, M.D. Snow Hill-buildings, London, E.C.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1866. *BURTON, FREDERICK M., F.G.S. Highfield, Gainsborough.
1887. *Bury, Henry. Trinity College, Cambridge.
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1878. ‡BUTCHER, J. G., M.A. 22 Collingham-place, London, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Clydesdale, Windsor.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1884. *Butterworth, W. Greenhill, Church-lane, Harpurhey, Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Ph.D. 298 Regent-street, London, W.

Year of
Election

1883. ‡Buxton, Miss F. M. Newnham College, Cambridge.
1887. *Buxton, J. H. 'Guardian' Office, Manchester.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 15 Eaton-place, London, S.W.
1883. ‡Buxton, Rev. Thomas, M.A. 19 Westcliffe-road, Birkdale, Southport.
1872. ‡Buxton, Sir Thomas Fowell, Bart., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. Seacombe, Cheshire.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. §Byrom, John R. Mere Bank, Fairfield, near Manchester.
1875. ‡Byrom, W. Ascroft, F.G.S. 31 King-street, Wigan.

1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. ‡Caird, Edward B. 8 Scotland-street, Glasgow.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1855. *Caird, James Tennant. Belleaire, Greenock.
1875. ‡Caldicott, Rev. J. W., D.D. The Rectory, Shipston-on-Stour.
1886. *Caldwell, William Hay. 12 Harvey-road, Cambridge.
1868. ‡Caley, A. J. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1887. §Callaway, Charles, M.A., D.Sc., F.G.S. Pembroke Lodge, Wellington, Shropshire.
1854. ‡Calver, Captain E. K., R.N., F.R.S. 23 Park-place East, Sunderland, Durham.
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡Cameron, Charles, M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, Sir CHARLES A., M.D. 15 Pembroke-road, Dublin.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1881. ‡*Cameron, Major-General, C.B. 3 Driffield-terrace, York.*
1884. ‡Campbell, Archibald H. Toronto, Canada.
1874. *CAMPBELL, Sir GEORGE, K.C.S.I., M.P., D.C.L., F.R.G.S., F.S.S. Southwell House, Southwell-gardens, South Kensington, London, S.W.; and Edenwood, Cupar, Fife.
1883. ‡Campbell, H. J. 81 Kirkstall-road, Talfourd Park, Streatham Hill, S.W.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
1876. ‡Campbell, James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1859. ‡Campbell, William. Dunmore, Argyllshire.
CAMPBELL-JOHNSTON, ALEXANDER ROBERT, F.R.S. 84 St. George's-square, London, S.W.
1862. *CAMPION, Rev. WILLIAM M., D.D. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1880. ‡Capper, Robert. Westbrook, Swansea.
1883. ‡Capper, Mrs. R. Westbrook, Swansea.
1887. §Capstick, John Walton. University College, Dundee.
1873. *CARBUTT, EDWARD HAMER. 19 Hyde Park-gardens, London, W.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
1883. ‡Carey-Hobson, Mrs. 54 Doughty-street, London, W.C.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.

Year of Election.

1876. ‡*Carlile, Thomas. 5 St. James's-terrace, Glasgow.*

CARLISLE, The Right Rev. HARVEY GOODWIN, D.D., D.C.L., Lord Bishop of. Carlisle.

1861. ‡*Carlton, James. Mosley-street, Manchester.*

1867. ‡Carmichael, David (Engineer). Dundee.

1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.

1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.

1884. ‡Carnegie, John. Peterborough, Ontario, Canada.

1885. *CARNELLEY, THOMAS, D.Sc., Professor of Chemistry in University College, Dundee.

1887. §Carpenter, A., M.D. Duppas House, Croydon.

1884. §Carpenter, Louis G. Agricultural College, Lansing, Michigan, U.S.A.

1871. *CARPENTER, P. HERBERT, D.Sc., F.R.S. Eton College, Windsor.

1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.

1872. §CARPENTER, WILLIAM LANT, B.A., B.Sc., F.C.S. 36 Craven-park, Harlesden, London, N.W

1884. *Carpmael, Charles. Toronto, Canada.

1867. ‡CARRUTHERS, WILLIAM, Pres.L.S., F.R.S., F.G.S. British Museum, London, S.W.

1886. ‡CARSLAKE J. BARHAM. 30 Westfield-road, Birmingham.

1883. §Carson, John. 51 Royal Avenue, Belfast.

1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.

1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.

1866. ‡Carter, H. H. The Park, Nottingham.

1855. ‡Carter, Richard, F.G.S. Cockerham Hall, Barnsley, Yorkshire.

1870. ‡Carter, Dr. William. 62 Elizabeth-street, Liverpool.

1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.

1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.

1878. *Cartwright, E. Henry. Magherafelt Manor, Co. Derry.

1870. §Cartwright, Joshua, M.Inst.C.E., Borough Surveyor. Bury, Lancashire.

1862. ‡Carulla, Facundo. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.

1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, London, S.W.

1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, London, S.W.

1883. §Carver, James. Garfield House, Elm-avenue, Nottingham.

1887. §Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.

1866. ‡Casella, L. P., F.R.A.S. The Lawns, Highgate, London, N.

1878. ‡Casey, John, LL.D., F.R.S., M.R.I.A., Professor of Higher Mathematics in the Catholic University of Ireland. 86 South Circular-road, Dublin.

1871. ‡Cash, Joseph. Bird-grove, Coventry.

1873. *Cash, William, F.G.S. 38 Elmfield-terrace, Saville Park, Halifax.

Castle, Charles. Clifton, Bristol.

1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. 18A Abercromby-square, Liverpool.

1859. ‡Catto, Robert. 44 King-street, Aberdeen.

1884. **Cave, Herbert. Christ Church, Oxford.*

1887. §Cawley, George. 3 Lansdowne-road, Didsbury, Manchester.

1886. ‡Cay, Albert. Ashleigh, Westbourne-road, Birmingham.

1860. §CAYLEY, ARTHUR, M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Garden House, Cambridge.

Cayley, Digby. Brompton, near Scarborough.

Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.

Year of Election.

1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1860. ‡CHADWICK, DAVID. The Poplars, Herne Hill, London, S.E.
1842. CHADWICK, EDWIN, C.B. Park Cottage, East Sheen, Middlesex, S.W.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1883. ‡Chalk, William. 24 Gloucester-road, Birkdale, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. ‡Chamberlain, Montague. St. John's, New Brunswick, Canada.
1883. ‡*Chambers, Benjamin. Hawkshead-street South, Southport.*
1883. ‡CHAMBERS, CHARLES, F.R.S. Colába Observatory, Bombay.
1883. ‡Chambers, Mrs. Colába Observatory, Bombay.
1883. ‡*Chambers, Charles, jun. The College, Cooper's Hill, Staines.*
1842. Chambers, George. High Green, Sheffield.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
*Champney, Henry Nelson. 4 New-street, York.
1881. *Champney, John E. Woodlands, Halifax.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 51 Prince's-gate, London, S.W.
1886. *Chance, John Horner. 40 Augustus-road, Edgbaston, Birmingham.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1877. §Chapman, T. Algernon, M.D. Burghill, Hereford.
1871. ‡Chappell, William, F.S.A. Strafford Lodge, Oatlands Park, Weybridge Station.
1874. ‡Charles, John James, M.A., M.D. 11 Fisherwick-place, Belfast.
1836. CHARLESWORTH, EDWARD, F.G.S. 277 Strand, London, W.C.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. Junior Garrick Club, Adelphi-terrace, London, W.C.
1886. §Chate, Robert W. Southfield, Edgbaston, Birmingham.
1883. ‡Chater, Rev. John. Part-street, Southport.
1884. *Chatterton, George. 46 Queen Anne's-gate, London, S.W.
1886. §Chattock, A. P. University College, Bristol.
1867. *Chatwood, Samuel, F.R.G.S. Irwell House, Drinkwater Park, Prestwich.
1884. ‡CHAUVEAU, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.
1887. §Cheetham, F. W. Limefield House, Hyde.
1887. §Cheetham, John. Limefield House, Hyde.
1874. *Chermside, Lieut.-Colonel H. C., R.E., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1879. *Chesterman, W. Broomsgrove-road, Sheffield.
1879. ‡*Cheyne, Commander J. P., R.N. 1 Westgate-terrace, West Brompton, London, S.W.*
CHICHESTER, The Right Rev. RICHARD DURNFORD, D.D., Lord Bishop of. Chichester.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Cowley House, Oxford.
1883. §Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 6 Place d'Armes, Ontario, Canada.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.

Year of Election.

1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. §Chorlton, J. Clayton. New Holme, Withington, Manchester.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
1884. *Christie, William. 13 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. 6 Barrow-road, Streatham Common, London, S.W.
1876. *CHRYSTAL, GEORGE, M.A., F.R.S.E., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §CHURCH, A. H., M.A., F.C.S., Professor of Chemistry to the Royal Academy of Arts, London. Shelsley, Ennerdale-road, Kew, Surrey.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1881. ‡CHURCHILL, Lord ALFRED SPENCER. 16 Rutland-gate, London, S.W.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1869. *Clapp, Frederick. Roseneath, St. James's-road, Exeter.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
1876. ‡Clark, David R., M.A. 31 Waterloo-street, Glasgow.
1877. *Clark, F. J. Street, Somerset.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
Clark, G. T. 44 Berkeley-square, London, W.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc., F.G.S. 20 Bootham, York.
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1883. ‡Clarke, Rev. Canon, D.D. 59 Hoghton-street, Southport.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
Clarke, George. Mosley-street, Manchester.
1886. §Clarke, Rev. H. J. Great Barr Vicarage, Birmingham.
1872. *CLARKE, HYDE. 32 St. George's-square, Pimlico, London, S.W.
1875. ‡CLARKE, JOHN HENRY. 4 Worcester-terrace, Clifton, Bristol.
1861. *Clarke, John Hope. 45 Nelson-street, Chorlton-on-Medlock, Manchester.
1877. ‡Clarke, Professor John W. University of Chicago, Illinois, U.S.A.
1851. ‡CLARKE, JOSHUA, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1850. ‡CLEGHORN, HUGH, M.D., F.L.S. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1873. ‡Cliff, John, F.G.S. Nesbit Hall, Fulneck, Leeds.
1886. ‡Clifford, Arthur. Beechcroft, Edgbaston, Birmingham.
1883. ‡Clift, Frederic, LL.D. Norwood, Surrey.

Year of
Election.

1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 40 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1883. *CLOWES, FRANK, D.Sc., F.C.S., Professor of Chemistry in University College, Nottingham. University College, Nottingham.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1885. §Clyne James. Rubislaw Den South, Aberdeen.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
Cobb, Edward. Falkland House, St. Ann's, Lewes.
1884. §Cobb, John. 29 Clarendon-road, Leeds.
1864. *Cochrane, James Henry. Elm Lodge, Prestbury, Cheltenham.
1884. *Cockburn-Hood, J. J. Walton Hall, Kelso, N.B.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Fairfield, Heaton, Bolton.
1881. §COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, London, S.W.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1884. *Cohen, B. L. 30 Hyde Park-gardens, London, W.
1887. §Cohen, Julius B. Hawkesmoor, Wilbraham-road, Fallowfield, Manchester.
1887. §Cohen, Sigismund. 111 Portland-street, Manchester.
1876. ‡*Colbourn, E. Rushton. 5 Marchmont-terrace, Hillhead, Glasgow.*
1853. ‡Colchester, William, F.G.S. Springfield House, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1876. ‡Colebrooke, Sir T. E., Bart., F.R.G.S. 14 South-street, Park-lane, London, W.; and Abington House, Abington, N.B.
1860. ‡COLEMAN, J. J., F.C.S. Ardarrode, Bearsden, near Glasgow.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1887. §Collie, Norman. Exeter Lawn, Grosvenor-street, Cheetham, Manchester.
1887. §Collier, Thomas. Ashfield, Alderley Edge, Manchester.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 2 Gipsy Hill-villas, Upper Norwood, Surrey, S.E.
1861. *Collingwood, J. Frederick, F.G.S. 96 Great Portland-street, London, W.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. ‡COLLINS, J. H., F.G.S. 64 Bickerton-road, London, N.
1876. ‡Collins, Sir William. 3 Park-terrace East, Glasgow.
1884. §Collins, William J., M.D., B.Sc. Albert-terrace, Regent's Park, London, N.W.
1883. ‡*Collis W. Elliott. 3 Lincoln's-Inn-fields, London, W.C.*
1868. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1882. ‡Colmer, Joseph G. Office of the High Commissioner for Canada, 9 Victoria-chambers, London, S.W.

Year of Election.

1884. ‡Colomb, Capt. J. C. R., M.P., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, London, S.W.
1870. ‡Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
1884. §Common, A. A., F.R.S., F.R.A.S. 63 Eaton-rise, Ealing, Middlesex, W.
1884. §Conklin, Dr. William A. Central Park, New York, U.S.A.
1852. ‡Connal, Sir Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Notting Hill House, Belfast.
1881. ‡Conroy, Sir John, Bart. Arborfield, Reading, Berks.
1876. ‡Cook, James. 162 North-street, Glasgow.
1882. ‡Cooke, Major-General A. C., R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Southampton.
1876. *Cooke, Conrad W. 2 Victoria-mansions, Victoria-street, London, S.W.
1881. ‡Cooke, F. Bishophill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
Cooke, J. B. Cavendish-road, Birkenhead.
1868. ‡Cooke, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishophill, York.
1859. *Cooke, His Honour Judge, M.A., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1883. §Cooke-Taylor, R. Whateley. Frenchwood House, Preston.
1883. ‡Cooke-Taylor, Mrs. Frenchwood House, Preston.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1883. ‡Coomer, John. Willaston, near Nantwich.
1884. ‡Coon, John S. 604 Main-street, Cambridge Pt., Massachusetts, U.S.A.
1883. ‡Cooper, George B. 67 Great Russell-street, London, W.C.
1850. ‡Cooper, Sir Henry, M.D. 7 Charlotte-street, Hull.
1838. Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1884. ‡Cooper, Mrs. M. A. West Tower, Marple, Cheshire.
1846. ‡Cooper, William White, F.R.C.S. 19 Berkeley-square, London, W.
1868. ‡Cooper, W. J. The Old Palace, Richmond, Surrey.
1884. ‡Cope, E. D. Philadelphia, U.S.A.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡Copeland, Ralph, Ph.D., F.R.A.S. Dun Echt, Aberdeen.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1885. ‡Copland, W., M.A. Tortorston, Peterhead, N.B.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1863. ‡Coppin, John. North Shields.
1842. Corbett, Edward. Grange Avenue, Levenshulme, Manchester.
1887. *Corcoran, Bryan. 31 Mark-lane, London, E.C.
1881. §Cordeaux, John. Great Cotes, Ulceby, Lincolnshire.
1883. *Core, Thomas H. Fallowfield, Manchester.
1870. *Corfield, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiène and Public Health in University College. 19 Savile-row, London, W.
1884. *Cornwallis, F. S. W. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Parkhill-road, Croydon.
1886. ‡Cossins, Jethro A. Warwick-chambers, Corporation-street, Birmingham.
1883. ‡Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, London, W.C.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. King-street, Manchester.

Year of Election.

1874. *COTTERILL, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
1879. ‡Cottrill, Gilbert I. Shepton Mallett, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1874. ‡Courtauld, John M. Bocking Bridge, Braintree, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1876. ‡Cowan, J. B., M.D. 4 Eglinton-crescent, Edinburgh.
1872. *Cowan, Thomas William, F.G.S. Comptons Lea, Horsham.
1886. §Cowen, Mrs. G. R. 9 The Ropewalk, Nottingham.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡Cowper, C. E. 6 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.Inst.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Lyndhurst, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. §Crabtree, William, M.Inst.C.E. Manchester-road, Southport.
1884. §CRAIGIE, Major P. G., F.S.S. 6 Lyndhurst-road, Hampstead, London, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1879. ‡Crampton, Thomas Russell, M.Inst.C.E. 19 Ashley-place, London, S.W.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.
1887. §Craven, John. Smedley Lodge, Cheetham, Manchester.
1887. *Craven, Thomas, J.P. Merlewood, Chorlton-cum-Hardy, Manchester.
1876. ‡*Crawford, Chalmond. Ridemon, Crosscar.*
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Slateford, Edinburgh.
1871. *CRAWFORD AND BALCARRES, The Right Hon. the Earl of, LL.D., F.R.S., F.R.A.S. The Observatory, Dun Echt, Aberdeen.
1883. *Crawshaw, Edward. 25 Tollington-park, London, N.
1870. *Crawshay, Mrs. Robert. Cathedine, Bwlch, Breconshire.
1885. §Creak, Staff Commander E. W., R.N., F.R.S. Richmond Lodge, Blackheath, London, S.E.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. George's Vicarage, Kendal.
1887. *Crewdson, Theodore. Norcliffe Hall, Styal, Cheshire.
1880. *Crisp, Frank, B.A., LL.B., F.L.S. 5 Lansdowne-road, Notting Hill, London, W.
1878. ‡Croke, John O'Byrne, M.A. The French College, Blackrock, Dublin.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.

Year of Election.

1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡Crombie, Charles W. 41 Carden-place, Aberdeen.
1885. ‡Crombie, John. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, John, jun. Daveston, Aberdeen.
1885. ‡CROMBIE, J. W., M.A. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. §Crompton, A. 1 St. James's-square, Manchester.
1886. ‡Crompton, Dickinson W. 40 Harborne-road, Edgbaston, Birmingham.
1887. §Crook, Henry T. 9 Albert-square, Manchester.
1870. ‡Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §CROOKES, WILLIAM, F.R.S., F.C.S. 7 Kensington Park-gardens, London, W.
1879. ‡Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1855. *Cropper, Rev. John. 8 The Polygon, Eccles, near Manchester.
1870. ‡Crosfield, C. J. 16 Alexandra-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William. Annesley, Aigburth, Liverpool.
1870. *Crosfield, William, jun. Annersley, Aigburth, Liverpool.
1887. §Cross, John. Beancliffe, Alderley Edge, Cheshire.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1883. ‡Cross, Rev. Prebendary, LL.B. Part-street, Southport.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1886. ‡Crosskey, Cecil. 117 Gough-road, Birmingham.
1867. §CROSSKEY, Rev. H. W., LL.D., F.G.S. 117 Gough-road, Birmingham.
1853. ‡Crosskill, William. Beverley, Yorkshire.
1870. *Crossley, Edward, M.P., F.R.A.S. Bemerside, Halifax.
1871. ‡Crossley, Herbert. Ferney Green, Bowness, Ambleside.
1866. *Crossley, Louis J., F.R.M.S. Moorside Observatory, near Halifax.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1883. §Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1861. ‡Crowley, Henry. Trafalgar-road, Birkdale Park, Southport.
1883. ‡Crowther, Elon. Cambridge-road, Huddersfield.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1860. ‡Cruickshank, John. Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1873. ‡Crust, Walter. Hall-street, Spalding.
1883. *Cryer, Major J. H. The Grove, Manchester-road, Southport.
Culley, Robert. Bank of Ireland, Dublin.
1883. *Culverwell, Edward P. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *Cunningham, Major Allan, R.E., A.I.C.E. Brompton Barracks, Chatham.
1887. §Cunningham, David. Viewbank, Newport, Fife, Scotland.
1877. *CUNNINGHAM, D. J., M.D., Professor of Anatomy in Trinity College, Dublin.
1852. ‡Cunningham, John. Macedon, near Belfast.
1885. ‡CUNNINGHAM, J. T., B.A., F.R.S.E. Scottish Marine Station, Granton, Edinburgh.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.

Year of Election.

1883. *Cunningham, Rev. William, B.D., D.Sc. Trinity College, Cambridge.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1881. ‡Curley, T., F.G.S. Hereford.
1885. §Curphey, William S. 268 Renfrew-street, Glasgow.
1884. §Currier, John McNab. Castleton, Vermont, U.S.A.
1867. *Cursetjee, Manockjee, F.R.G.S., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡CURTIS, ARTHUR HILL, LL.D. 1 Hume-street, Dublin.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, London, S.W.

1854. ‡Daglish, Robert, M.Inst.C.E. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1887. §Dale, Henry F., F.R.M.S., F.Z.S. Sutgrove, Miserden, Gloucestershire.
1863. ‡Dale, J. B. South Shields.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡DALLINGER, Rev. W. H., LL.D., F.R.S., F.L.S. Wesley College, Glossop-road, Sheffield.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
*Dalton, Rev. J. E., B.D. Seagrave, Loughborough.
1862. ‡DANBY, T. W., M.A., F.G.S. 1 Westbourne-terrace-road, London, W.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1883. ‡Darbishire, S. D., M.D. 60 High-street, Oxford.
1876. ‡Darling, G. Erskine. 247 West George-street, Glasgow.
1884. ‡Darling, Thomas. 99 Drummond-street, Montreal, Canada.
1882. ‡DARWIN, FRANCIS, M.A., F.R.S., F.L.S. Huntingdon-road, Cambridge.
1881. *DARWIN, GEORGE HOWARD, M.A., LL.D., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1878. *Darwin, Horace. The Orchard, Huntingdon-road, Cambridge.
1882. §Darwin, W. E., F.G.S. Bassett, Southampton.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1878. ‡*D'Aulmay, G. 22 Upper Leeson-street, Dublin.*
1872. ‡Davenport, John T. 64 Marine Parade, Brighton.
1880. §DAVEY, HENRY, M.Inst.C.E. 3 Prince's-street, Westminster, S.W.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, London, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1842. Davies-Colley, Dr. Thomas. Newton, near Chester.

Year of Election.

1887. §Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. Parliament Mansions, London, S.W.
1870. *Davis, A. S. 6 Paragon-buildings, Cheltenham.
1864. ‡Davis, Charles E., F.S.A. 55 Pulteney-street, Bath.
1887. §Davis, David. 55 Berkley-street, Liverpool.
Davis, Rev. David, B.A. Lancaster.
1881. ‡Davis, George E. The Willows, Fallowfield, Manchester.
1882. §Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1873. *Davis, James W., F.G.S., F.S.A. Chevinedge, near Halifax.
1856. *Davis, Sir John Francis, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, near Compton, Bristol.
1883. ‡Davis, Joseph, J.P. Park-road, Southport.
1883. ‡Davis, Robert Frederick, M.A. Earlsfield, Wandsworth Common, London, S.W.
1885. *Davis, Rudolf. Castle Howell School, Lancaster.
1882. ‡*Davis, W. H. Gloucester Lodge, Portswood, Southampton.*
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡Davison, Charles, M.A. 38 Charlotte-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡Davy, Edmund W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. M. Bedford-circus, Exeter.
1860. *Dawes, John T., F.G.S. Blaen-y-Roe, St. Asaph, North Wales.
1864. ‡Dawkins, W. Boyd, M.A., F.R.S., F.G.S., F.S.A., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. §Dawson, Bernard. The Laurels, Malvern Link.
1885. *Dawson, Captain H. P., R.A. Junior United Service Club, Pall Mall, London, S.W.
Dawson, John. Barley House, Exeter.
1884. ‡Dawson, Samuel. 258 University-street, Montreal, Canada.
1855. §Dawson, Sir William, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal of McGill University. McGill University, Montreal, Canada.
1859. *Dawson, Captain William G. Plumstead Common, Kent.
1879. ‡Day, Francis. Kenilworth House, Cheltenham.
1871. ‡Day, St. John Vincent, M.Inst.C.E., F.R.S.E. 166 Buchanan-street, Glasgow.
1870. *Deacon, G. F., M.Inst.C.E. Municipal Offices, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1887. §Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, B.A., D.Sc., F.G.S. 38 Wellington-road, Birmingham.
1884. *Debenham, Frank, F.S.S. 26 Upper Hamilton-terrace, London, N.W.
1866. ‡Debus, Heinrich, Ph.D., F.R.S., F.C.S., Lecturer on Chemistry at Guy's Hospital, London, S.E.
1884. §Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1882. *De Chaumont, François, M.D., F.R.S., Professor of Hygiène in the Royal Victoria Hospital, Netley.
1887. §Dehn, R. Olga Villa, Victoria Park, Manchester.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1854. *De La Rue, Warren, M.A., D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. 73 Portland-place, London, W.
1879. ‡De la Sala, Colonel. Sevilla House, Navarino-road, London, N.W.

Year of
Election.

1884. *De Laune, C. DeL. F. Sharsted Court, Sittingbourne.
1887. §De Meschin, Miss Hannah Constance. Sandycove Castle, Kingstown, Ireland.
1870. ‡De Meschin, Thomas, B.A., LL.D. Sandycove Castle, Kingstown, Ireland.
Denchar, John. Morningside, Edinburgh.
1873. ‡Denham, Thomas. Huddersfield.
1884. ‡Denman, Thomas W. Lamb's-buildings, Temple, London, E.C.
Dent, William Yerbury. Royal Arsenal, Woolwich.
1870. *Denton, J. Bailey. Orchard Court, Stevenage.
1874. §De Rance, Charles E., F.G.S. 28 Jermyn-street, London, S.W.
1856. *Derby, The Right Hon. the Earl of, K.G., M.A., LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Henleaze Park, Westbury-on-Trym, Bristol.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
De Tabley, George, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡Devon, The Right Hon. the Earl of, D.C.L. Powderham Castle, near Exeter.
*Devonshire, His Grace the Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡Dewar, James, M.A., F.R.S. L. & E., F.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural Experimental Philosophy in the University of Cambridge. 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Mrs. 1 Scroope-terrace, Cambridge.
1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William. 6 Montpellier-grove, Cheltenham.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 2 Southwick-place, Hyde Park, London, W.
1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *Dew-Smith, A. G., M.A. Trinity College, Cambridge.
1883. ‡Dickinson, A. P. Fair Elms, Blackburn.
1864. *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1887. §Dickinson, Joseph, F.G.S. South Bank, Pendleton.
1884. ‡Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund. West Cliff, Preston.
1887. §Dickson, H. N. 38 York-place, Edinburgh.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡Dickson, T. A. West Cliff, Preston.
1862. *Dilke, The Right Hon. Sir Charles Wentworth, Bart., F.R.G.S. 76 Sloane-street, London, S.W.
1877. §Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1848. ‡Dillwyn, Lewis Llewelyn, M.P., F.L.S., F.G.S. Parkwerne, near Swansea.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1876. ‡Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.

Year of Election.

1868. ‡Dittmar, William, F.R.S. L. & E., F.C.S., Professor of Chemistry in Anderson's College, Glasgow.
1884. §Dix, John William H. Bristol.
1874. *Dixon, A. E. Dunowen, Cliftonville, Belfast.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.
1853. ‡Dixon, Edward. Wilton House, Southampton.
1886. ‡Dixon, George. 42 Augustus-road, Edgbaston, Birmingham.
1879. *Dixon, Harold B., M.A., F.R.S., F.C.S., Professor of Chemistry in the Owens College, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1887. §Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.
1885. §Dobbin, Leonard. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne Park, London, W.
1878. *Dobson, G. E., M.A., M.B., F.R.S., F.L.S. Colyford Villa, Exeter.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
1875. *Docwra, George, jun. Liberal Club, Colchester.
1870. *Dodd, John. 34 Fern-grove, Lodge-lane, Liverpool.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡*Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.*
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
1887. *Donald, Provost Robert. City Chambers, Dunfermline, Scotland.
1885. ‡Donaldson, James, M.A., LL.D., F.R.S.E., Regius Professor of Humanity in the University of Aberdeen. Old Aberdeen.
1882. ‡Donaldson, John. Tower House, Chiswick, Middlesex.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, jun. May's Hill, Shortlands, Kent.
1874. ‡Donnell, Professor, M.A. 76 Stephen's-green South, Dublin.
1861. ‡Donnelly, Colonel, R.E., C.B. South Kensington Museum, London, W.
1887. §Donner, Edward, B.A. 4 Anson-road, Victoria Park, Manchester.
1887. §Dorning, Elias, M.Inst.C.E., F.G.S. 41 John Dalton-street, Manchester.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863. *Doughty, Charles Montagu. Care of H. M. Doughty, Esq., 5 Stone-court, Lincoln's Inn, London, W.C.
1876. *Douglas, Rev. G. C. M. 18 Royal-crescent West, Glasgow.
1877. *Douglass, Sir James N., F.R.S., M.Inst.C.E. Trinity House, London, E.C.
1878. ‡Douglass, William. 104 Baggot-street, Dublin.
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1886. ‡Dovaston, John. West Felton, Shropshire.
1883. §Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. St. Leonard's, St. Andrews, N.B.
1884. ‡Dove, P. Edward, F.R.A.S., Sec.R.Hist.Soc. 23 Old-buildings, Lincoln's Inn, London, W.C.
1884. ‡Dowe, John Melnotte. 69 Seventh-avenue, New York, U.S.A.
1870. ‡Dowie, J. Muir. Gollanol, by Kinross, N.B.
1876. ‡Dowie, Mrs. Muir. Gollanol, by Kinross, N.B.
1884. *Dowling, D. J. Bromley, Kent.
1878. ‡Dowling, Thomas. Claireville House, Terenure, Dublin.
1857. ‡Downing, S., LL.D. 4 The Hill, Monkstown, Co. Dublin.

Year of Election.

1878. ‡Dowse, The Right Hon. Baron. 38 Mountjoy-square, Dublin.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, Joseph Emerson, M.Inst.C.E. 3 Great Queen-street, London, S.W.
1887. §Doxey, R. A. Slade House, Levenshulme, Manchester.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1868. ‡DRESSER, HENRY E., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1873. §DREW, FREDERIC, F.G.S., F.R.G.S. Eton College, Windsor.
1879. ‡Drew, Samuel, M.D., D.Sc., F.R.S.E. 10 Laura-place, Bath.
1887. §Dreyfus, Dr. Daisy Mount, Victoria Park, Manchester.
1870. §Drysdale, J. J., M.D. 36A Rodney-street, Liverpool.
1884. ‡*Du Bois, Henri.* 39 *Bentick-street, Glasgow.*
1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Holme House, Columbia-road, Oxton, Birkenhead.
1867. *DUFF, The Right Hon. Sir MOUNTSTUART ELPHINSTONE GRANT-, G.C.B., G.C.S.I., F.R.S., F.R.G.S. York House, Twickenham.
1852. ‡Dufferin and Clandeboye, The Right Hon. the Earl of, K.P., G.C.B., LL.D., F.R.S., F.R.G.S., Governor-General of India. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1884. §Dugdale, James H. 9 Hyde Park-gardens, London, W.
1883. §Duke, Frederic. Conservative Club, Hastings.
1859. *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1866. *Duncan, James. 9 Mincing-lane, London, E.C.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1867. ‡DUNCAN, PETER MARTIN, M.B., F.R.S., F.G.S., Professor of Geology in King's College, London. 6 Grosvenor-road, Gunnersbury, London, W.
1880. ‡Duncan, William S. 22 Delamere-terrace, Bayswater, London, W.
1881. ‡Duncombe, The Hon. Cecil. Nawton Grange, York.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. §Dunn, J. T., M.Sc., F.C.S. High School for Boys, Gateshead-on-Tyne.
1883. ‡Dunn, Mrs. 115 Scotswood-road, Newcastle-on-Tyne.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1884. §Dunnington, F. P. University of Virginia, Albemarle Co., Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1885. *Dunstan, Wyndham, F.C.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 17 Bloomsbury-square, London, W.C.
1866. ‡Duprey, Perry. Woodberry Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡DURHAM, ARTHUR EDWARD, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
1887. §Durham, William. Seaforth House, Portobello, Scotland.
1887. §Dyason, John Sanford, F.R.G.S., F.R.Met.Soc. Boscobel-gardens, London, N.W.

Year of Election.

1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A. 8 Highburgh-terrace, Dowanhill, Glasgow.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1883. ‡Eagar, Rev. Thomas. The Rectory, Ashton-under-Lyne.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1833. *Earnshaw, Rev. Samuel, M.A. 14 Beechhill-road, Sheffield.
1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *Easton, Edward, M.Inst.C.E., F.G.S. 11 Delahay-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. §Eastwood, Miss. Littleover Grange, Derby.
1887. §Eccles, Mrs. S. White Coppice, Chorley, Lancashire.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Syward Lodge, Dorchester.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. §Ede, Francis J. Silchar, Cachar, India.
Eden, Thomas. Talbot-road, Oxton.
1884. *Edgell, R. Arnold, M.A., F.C.S. Ashburnham House, Little Dean's-yard, Westminster, S.W.
1887. §Edgeworth, F. Y., M.A., F.S.S. Savile Club, 107 Piccadilly, London, W.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 72 Portsdown-road, London, W.
1883. ‡Edmonds, William. Wiscombe Park, Honiton, Devon.
1884. *Edmunds, James, M.D. 8 Grafton-street, Piccadilly, London, W.
1883. ‡Edmunds, Lewis, D.Sc., LL.B. 60 Park-street, Park-lane, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. ‡Edward, Charles. Chambers, 8 Bank-street, Dundee.
1855. *Edwards, Professor J. Baker, Ph.D., D.C.L. Montreal, Canada.
1884. ‡Edwards, W. F. Niles, Michigan, U.S.A.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1885. *Elgar, Francis, LL.D., F.R.S.E., Director of H.M. Dockyards. The Admiralty, London, S.W.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. Manor Cottage, Kempston, Bedford.
1863. ‡Ellenberger, J. L. Worksop.
1885. §Ellingham, Frank. Thorpe St. Andrew, Norwich.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1880. *Elliot, Colonel Charles, C.B. 18 Roland-gardens, London, S.W.
1864. ‡Elliott, E. B. Washington, U.S.A.
1883. *Elliott, Edwin Bailey, M.A. Queen's College, Oxford.
1872. ‡*Elliott, Rev. E. B.* 11 *Sussex-square, Kemp Town, Brighton.*
Elliott, John Fogg. Elvet Hill, Durham.
1879. §Elliott, Joseph W. Post Office, Bury, Lancashire.
1886. §Elliott, Thomas Henry, F.S.S. Inland Revenue Department, Somerset House, London, W.C.

Year of Election.

1864. *ELLIS, ALEXANDER JOHN, B.A., F.R.S., F.S.A. 25 Argyll-road, Kensington, London, W.
1877. ‡Ellis, Arthur Devonshire. School of Mines, Jermyn-street, London, S.W.; and Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. 6 Westbourne-terrace, Hyde Park, London, W.
1883. ‡Ellis, John. 17 Church-street, Southport.
1880. *ELLIS, JOHN HENRY. New Close, Cambridge-road, Southport.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1864. ‡Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
1884. ‡Ellis, W. Hodgson. Toronto, Canada.
1869. ‡ELLIS, WILLIAM HORTON. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. §Elmy, Ben. Eaton Hall, Congleton, Manchester.
1862. ‡Elphinstone, H. W., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, London, W.C.
1883. ‡Elwes, George Robert. Bossington, Bournemouth.
1887. §Elworthy, Frederick T. Foxdown, Wellington, Somerset.
1870. *ELY, The Right Rev. Lord ALWYNE COMPTON, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1886. ‡Emmons, Hamilton. Mount Vernon Lodge, Leamington.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡English, J. T. Wayfield House, Stratford-on-Avon.
1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.
1844. ‡Erichsen, John Eric, LL.D., F.R.S., F.R.C.S., Professor of Surgery in University College, London. 6 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.
1885. ‡Esselmont, Peter, M.P. 34 Albyn-place, Aberdeen.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.C.S., F.R.A.S. Merton College, and 13 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.
1887. *Estcourt, Charles. Vyrnieu House, Talbot-road, Old Trafford, Manchester.
1887. *Estcourt, P. A. Vyrnieu House, Talbot-road, Old Trafford, Manchester.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. ‡ETHERIDGE, ROBERT, F.R.S. L. & E., F.G.S., Assistant Keeper (Geological and Palæontological Department) Natural History Museum (British Museum). 14 Carlyle-square, London, S.W.
1883. §Eunson, Henry J. 20 St. Giles-street, Northampton.
1881. ‡Evans, Alfred. Exeter College, Oxford.
1870. *Evans, Arthur John, F.S.A. 33 Holywell, Oxford.
1865. *EVANS, Rev. CHARLES, M.A. The Rectory, Solihull, Birmingham.
1884. §Evans, Horace L. Moreton House, Tyndall Park, Bristol.
1869. *Evans, H. Saville W. Wimbledon Park House, Wimbledon, Surrey.

Year of Election.

1861. *EVANS, JOHN, D.C.L., LL.D., Treas.R.S., F.S.A., F.L.S., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempstead.
1883. §Evans, J. C. Nevill-street, Southport.
1883. §Evans, Mrs. J. C. Nevill-street, Southport.
1881. ‡Evans, Lewis. Llanfyrnach R.S.O., Pembrokeshire.
1876. ‡Evans, Mortimer, M.Inst.C.E. 97 West Regent-street, Glasgow.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. Heathfield, Alleyne Park, Lower Norwood, Surrey, S.E.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1865. *Evans, William. The Spring, Kenilworth.
1886. ‡Eve, A. S. Marlborough College, Wilts.
1871. §Eve, H. Weston, M.A. University College, London, W.C.
1868. *EVERETT, J. D., M.A., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in Queen's College, Belfast. 5 Prince's-gardens, Belfast.
1880. ‡Everingham, Edward. St. Helen's-road, Swansea.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1886. §Everitt, William E. Finstall Park, Bromsgrove.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡EWART, J. COSSAR, M.D., Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, William, M.P. Glenmachan, Belfast.
1874. ‡Ewart, W. Quartus. Glenmachan, Belfast.
1859. *Ewing, Sir Archibald Orr, Bart., M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1876. *EWING, JAMES ALFRED, B.Sc., F.R.S. L. & E., Professor of Engineering in University College, Dundee.
1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1884. §Eyerman, John. Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1884. ‡Fairbairn, Dr. A. M. Airedale College, Bradford, Yorkshire.
1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1876. ‡*Fairlie, James M. Charing Cross Corner, Glasgow.*
1870. ‡Fairlie, Robert. Woodlands, Clapham Common, London, S.W.
1886. §Fairley, William. Beau Desert, Rugeley, Staffordshire.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1886. ‡Fallon, T. P., Consul General. Australia.
1883. ‡Fallon, Rev. W. S. 1 St. Alban's-terrace, Cheltenham.
1877. §FARADAY, F. J., F.L.S., F.S.S. College Chambers, 17 Brazenose-street, Manchester.
1887. §Farmer, Sir James. Hope House, Eccles Old-road, Manchester.
1886. §Farncombe, Joseph, J.P. Lewes.
1879. *Farnworth, Ernest. Clarence Villa, Penn Fields, Wolverhampton.
1883. §Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1859. ‡Farquharson, Robert F. O. Haughton, Aberdeen.
1885. ‡Farquharson, Mrs. R. F. O. Haughton, Aberdeen.
1866. *FARRAR, Ven. FREDERICK WILLIAM, M.A., D.D., F.R.S., Archdeacon of Westminster. St. Margaret's Rectory, Westminster, S.W.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.

Year of Election.

1869. *Faulding, Joseph. Ebor Villa, Godwin-road, Clive-vale, Hastings.
1883. §Faulding, Mrs. Ebor Villa, Godwin-road, Cive-vale, Hastings.
1887. §Faulkner, John. 13 Great Ducie-street, Strangeways, Manchester.
1863. ‡*Fawcus, George. Alma-place, North Shields.*
1873. *Fazakerley, Miss. Banwell Abbey, Weston-super-Mare, Somerset.
1886. §Felkin, Robert W., M.D., F.R.G.S. 20 Alva-street, Edinburgh.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. *Fellows, Frank P., K.S.J.J., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square; and Keswick, near Belfast.
1883. ‡Fenwick, E. H. 29 Harley-street, London, W.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. ‡Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. *Ferguson, John, M.A., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Sir Samuel, LL.D., Q.C. 20 Great George's-street North, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1883. ‡Fernald, H. P. Alma House, Cheltenham.
1883. *Fernie John. 113 South 40th Street, Philadelphia, U.S.A.
1862. ‡Ferrers, Rev. Norman Macleod, D.D., F.R.S. Caius College Lodge, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., F.R.S., Professor of Forensic Medicine in King's College. 34 Cavendish-square, London, W.
1882. §Fewings, James, B.A., B.Sc. The Grammar School, Southampton.
1887. §Fiddes, Thomas, M.D. Penwood, Urmston, near Manchester.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1886. ‡Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.
1869. *Field, Rogers, B.A., M.Inst.C.E. 4 Westminster-chambers, Westminster, S.W.
1887. §Fielden, John C. 145 Upper Brook-street, Manchester.
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. **Finch, Gerard B., M.A. 10 Lyndhurst-road, London, N.W.*
1883. ‡*Finch, Mrs. Gerard. 10 Lyndhurst-road, London, N.W.*
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1885. ‡Findlater, John. 60 Union-street, Aberdeen.
1878. *Findlater, William. 22 Fitzwilliam-square, Dublin.
1885. ‡Findlay, George, M.A. 50 Victoria-street, Aberdeen.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. §Finnemore, Rev. J., F.G.S. 175 Oldham-road, Manchester.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *Fischer, Professor William L. F., M.A., LL.D., F.R.S. St. Andrews, N.B.
1858. ‡Fishbourne, Admiral E. G., R.N. 26 Hogarth-road, Earl's Court-road, London, S.W.
1884. *Fisher, L. C. Galveston, Texas, U.S.A.
1869. ‡Fisher, Rev. Osmond, M.A., F.G.S. Harlton Rectory, near Cambridge.
1873. ‡Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.

Year of Election.

1879. ‡Fisher, William. Norton Grange, near Sheffield.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1887. *Fison, Alfred H., D.Sc. 1 Melcombe-place, Dorset-square, London, N.W.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *Fison, Frederick W., M.A., F.C.S. Eastmoor, Ilkley, Yorkshire.
1871. ‡Fitch, J. G., M.A., LL.D. 5 Lancaster-terrace, Regent's Park, London, N.W.
1883. ‡Fitch, Rev. J. J. Ivyholme, Southport.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §Fitzgerald, George Francis, M.A., F.R.S., Professor of Natural and Experimental Philosophy. Trinity College, Dublin.
1885. *Fitzgerald, Professor Maurice, B.A. 37 Botanic-avenue, Belfast.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.
1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡*Fleming, Professor Alexander, M.D.* 121 *Hagley-road, Birmingham.*
1881. ‡Fleming, Rev. Canon James, B.D. The Residence, York.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
1867. §Fletcher, Alfred E., F.C.S. 57 Gordon-square, London, W.C.
1870. ‡Fletcher, B. Edgington. Norwich.
1886. ‡Fletcher, Frank M. 57 Gordon-square, London, W.C.
1869. ‡Fletcher, Lavington E., M.Inst.C.E. Alderley Edge, Cheshire.
1862. §Flower, William Henry, C.B., LL.D., F.R.S., F.L.S., F.G.S., F.R.C.S., Director of the Natural History Department, British Museum, South Kensington, London, S.W.
1877. *Floyer, Ernest A., F.R.G.S., F.L.S. Cairo.
1887. §Foale, William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1883. ‡Foale, Mrs. William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1881. ‡Foljambe, Cecil G. S., M.P. 2 Carlton House-terrace, Pall Mall, London, S.W.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1879. ‡Foote, Harry D'Oyley, M.D. Rotherham, Yorkshire.
1880. ‡Foote, R. Bruce. Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.
1873. *Forbes, George, M.A., F.R.S. L. & E. 34 Great George-street, London, S.W.
1883. ‡Forbes, Henry O., F.Z.S. Rubislaw Den, Aberdeen.
1885. ‡Forbes, The Right Hon. Lord. Castle Forbes, Aberdeenshire.
1866. ‡*Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.*
1875. *Fordham, H. George, F.G.S. Odsey Grange, Royston, Cambridgeshire.
1883. §Formby, R. Formby, near Liverpool.
1887. §Forrest, John, C.M.G., F.R.G.S. Perth, Western Australia.
1867. ‡Forster, Anthony. Finlay House, St. Leonard's-on-Sea.
1883. ‡Forsyth, A. R. Trinity College, Cambridge.
1884. ‡Fort, George H. Lakefield, Ontario, Canada.
1854. *Fort, Richard. Read Hall, Whalley, Lancashire.
1877. ‡Fortescue, The Right Hon. the Earl. Castle Hill, North Devon.
1882. §Forward, Henry. 2 St. Agnes-terrace, Victoria Park-road, London, E.

Year of Election.

1870. ‡Forwood, Sir William B. Hopeton House, Seaforth, Liverpool.
1875. ‡Foster, A. Le Neve. 51 Cadogan-square, London, S.W.
1865. ‡Foster, Balthazar, M.D., Professor of Medicine in Queen's College, Birmingham. 16 Temple-row, Birmingham.
1865. *Foster, Clement Le Neve, B.A., D.Sc., F.G.S. Llandudno.
1883. ‡Foster, Mrs. C. Le Neve. Llandudno.
1857. *Foster, George Carey, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 18 Daleham-gardens, Hampstead, London, N.W.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *Foster, Michael, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S., Professor of Physiology in the University of Cambridge. Trinity College, and Great Shelford, near Cambridge.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1876. *Fowler, John. 4 Kelvin Bank-terrace, Glasgow.
1882. ‡Fowler, Sir John, K.C.M.G., M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1870. *Fowler, Sir Robert Nicholas, Bart., M.A., M.P., F.R.G.S. 50 Cornhill, London, E.C.
1884. ‡Fox, Miss A. M. Penjerrick, Falmouth.
1883. *Fox, Charles. 28 Glasshouse-street, Regent-street, London, W.
1883. §Fox, Sir Charles Douglas, M.Inst.C.E. 5 Delahay-street, Westminster, S.W.
1860. *Fox, Rev. Edward, M.A. Upper Heyford, Banbury.
1883. ‡Fox, Howard, United States Consul. Falmouth.
1876. *Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Lordship-terrace, Stoke Newington, London, N.
1876. ‡Fox, St. G. Lane. 9 Sussex-place, London, S.W.
1886. ‡Foxwell, Arthur, M.A., M.B. 17 Temple-row, Birmingham.
1881. *Foxwell, Herbert S., M.A., F.S.S., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1866. *Francis, G. B. Vale House, Hertford.
1884. ‡Francis, James B. Lowell, Massachusetts, U.S.A.
Francis, William, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡Frankland, Edward, M.D., D.C.L., LL.D., Ph.D., F.R.S., F.C.S. The Yews, Reigate Hill, Surrey.
1887. §Frankland, Percy F., Ph.D. Royal School of Mines, South Kensington, London, S.W.
1882. §Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1885. ‡Fraser, Angus, M.A., M.D., F.C.S. 232 Union-street, Aberdeen.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James William. 8a Kensington Palace-gardens, London, W.
1865. *Fraser, John, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡Fraser, Thomas R., M.D., F.R.S. L. & E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 37 Melville-street, Edinburgh.
1859. *Frazer, Daniel. 127 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc., Professor of Chemistry in the Franklin Institute of Pennsylvania. 917 Clinton-street, Philadelphia, U.S.A.

Year of Election.

1884. *FREAM, W., B.Sc., F.L.S., F.G.S., F.S.S., Professor of Natural History in the College of Agriculture, Downton, Salisbury.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester.
1877. §Freeman, Francis Ford. 8 Leigham-terrace, Plymouth.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
1880. ‡Freeman, Thomas. Brynhyfryd, Swansea.
1841. Freeth, Major-General S. 30 Royal-crescent, Notting Hill, London, W.
1884. *Fremantle, Hon. C. W., C.B. Royal Mint, London, E.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
1886. ‡Freshfield, Douglas W., Sec.R.G.S. 1 Savile-row, London, W.
1886. ‡Freund, Miss Ida. Eyre Cottage, Upper Sydenham, S.E.
1887. §Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1857. *Frith, Richard Hastings, M.R.I.A., F.R.G.S.I. 48 Summer-hill, Dublin.
1883. ‡Froane, William. Beech House, Birkdale, Southport.
1887 §Froehlich, The Chevalier. Grosvenor-terrace, Withington, Manchester.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1883. ‡Frost, Major H., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. St. James's Chambers, Duke-street, London, S.W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
1884. §Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1872. *Fuller, Rev. A. Pallant, Chichester.
1859. ‡FULLER, FREDERICK, M.A. 9 Palace-road, Surbiton.
1869. ‡FULLER, GEORGE, M.Inst.C.E. 71 Lexham-gardens, Kensington, London, W.
1884. §Fuller, William. Oswestry.

1881. ‡Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire.
1887. §Gaddum, G. H. Adria House, Toy-lane, Withington, Manchester.
*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡GAGES, ALPHONSE, M.R.I.A. Museum of Irish Industry, Dublin.
1863. **Gainsford, W. D. Aswardby Hall, Spilsby.*
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡Gairdner, Professor W. T., M.D. 225 St. Vincent-street, Glasgow.
GALBRAITH, Rev. J. A., M.A., M.R.I.A. Trinity College, Dublin.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 225 Oxford-street, London, W.
1885. *Gallaway, Alexander. Tighnault, Aberfeldy, N.B.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. The Cottage, Seymour-grove, Old Trafford, Manchester.
1860. *GALTON, Sir DOUGLAS, K.C.B., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, M.A., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. 40 Great Marlborough-street, London, W.
1887. *Galton, Miss Laura Gwendolen Douglas. 12 Chester-street, Grosvenor-place, London, S.W.

Year of Election.

1870. §Gamble, Lieut.-Colonel D. St. Helen's, Lancashire.
1870. ‡Gamble, J. C. St. Helen's, Lancashire.
1872. *Gamble, John G., M.A. Capetown. (Care of Messrs. Ollivier and Brown, 37 Sackville-street, Piccadilly, London, W.)
1877. ‡Gamble, William. St. Helen's, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S., Fullerian Professor of Physiology in the Royal Institution, London. 11 Warrior-square, St. Leonard's-on-Sea.
1883. ‡Gant, Major John Castle. St. Leonard's.
1887. §GARDINER WALTER, M.A. Clare College, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. 25 Northbrook-road, Lee, Kent.
1882. ‡Gardner, John Starkie, F.G.S. 7 Damer-terrace, Chelsea, London, S.W.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1862. ‡GARNER, ROBERT, F.L.S. Stoke-upon-Trent.
1865. ‡Garner, Mrs. Robert. Stoke-upon-Trent.
1887. *Garnett, J. W. The Grange, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L., Principal of the College of Physical Science, Newcastle-on-Tyne.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. §Garson, J. G., M.D. 14 Suffolk-street, Pall Mall, London, S.W.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1847. *Gaskell, Samuel. Church House, Weybridge.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Place, East Grinstead, Sussex.
1875. ‡Gavey, J. 43 Stacey-road, Routh, Cardiff.
1875. ‡Gaye, Henry S., M.D. Newton Abbot, Devon.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. ‡Geddes, John. 33 Portland-street, Southport.
1885. §Geddes, Patrick. 6 James-court, Edinburgh.
1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1887. §Gee, W. W. Haldane. Denbigh Meadows, Heaton Chapel, Stockport.
1867. ‡GEIKIE, ARCHIBALD, LL.D., F.R.S. L. & E., F.G.S., Director-General of the Geological Survey of the United Kingdom. Geological Survey Office, Jermyn-street, London, S.W.
1871. ‡Geikie, James, LL.D., F.R.S. L. & E., F.G.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. 10 Bright's-crescent, Mayfield, Edinburgh.
1882. *Genese, R. W., M.A., Professor of Mathematics in University College, Aberystwith.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1885. ‡Gerard, Robert. Blair-Devenick, Cults, Aberdeen.
1884. *Gerrans, Henry T., M.A. Worcester College, Oxford.
1870. *Gervis, Walter S., M.D., F.G.S. Ashburton, Devonshire.
1884. ‡Gibb, Charles. Abbotsford, Quebec, Canada.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1874. ‡Gibson, The Right Hon. Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E., Secretary to the Royal College of Physicians of Edinburgh. 17 Alva-street, Edinburgh.

Year of Election.

1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1885. §Gibson, John, Ph.D. The University, Edinburgh.
1887. §Giffen, Robert, LL.D., V.P.S.S. 44 Pembroke-road, London, S.W.
1884. ‡Gilbert, E. E. 245 St. Antoine-street, Montreal, Canada.
1842. Gilbert, Joseph Henry, Ph.D., LL.D., F.R.S., F.C.S., Professor of Rural Economy in the University of Oxford. Harpenden, near St. Albans.
1883. §Gilbert, Mrs. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 245 St. Antoine-street, Montreal, Canada.
1883. ‡Gilbert, Thomas. Derby-road, Southport.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1882. ‡Giles, Alfred, M.P., M.I.C.E. Cosford, Godalming.
1878. ‡Giles, Oliver. Park Side, Cromwell-road, St. Andrew's, Bristol.
Giles, Rev. William. Netherleigh House, near Chester.
1878. ‡Gill, Rev. A. W. H. 44 Eaton-square, London, S.W.
1871. *Gill, David, LL.D., F.R.S. Royal Observatory, Cape Town.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1864. ‡Gill, Thomas. 4 Sydney-place, Bath.
1887. §Gillett, Charles Edwin. Wood Green, Banbury, Oxford.
1884. ‡Gillman, Henry. 79 East Columbia-street, Detroit, Michigan, U.S.A.
1861. *Gilroy, George. Woodlands, Parbold, near Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1887. *Gimingham, Charles H. Stamford House, Northumberland Park, Tottenham, Middlesex.
1867. §Ginsburg, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1884 ‡Gisborne, Frederick Newton. Ottawa, Canada.
1886. *Gisborne, Hartley. Battleford, Saskatchewan District, Canada.
1883. *Gladstone, Miss. 17 Pembridge-square, London, W.
1883. *Gladstone, Miss E. A. 17 Pembridge-square, London, W.
1850. *Gladstone, George, F.C.S., F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1849. *Gladstone, John Hall, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, London, W.
1861. *Glaisher, James, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *Glaisher, J. W. L., M.A., D.Sc., F.R.S., Pres.R.A.S. Trinity College, Cambridge.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *Glazebrook, R. T., M.A., F.R.S. Trinity College, Cambridge.
1887. §Glazier, Walter H. Courtlands, East Molesey, Surrey.
1881. *Gleadow, Frederic. Forth Bridge Works, South Queensferry, N.B.
1870. §Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
Glover, Thomas. 124 Manchester-road, Southport.
1887. §Glover, Walter T. Moorhurst, Kersal, Manchester.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. ‡Goddard, Richard. 16 Booth-street, Bradford, Yorkshire.
1886. ‡Godlee, Arthur. 3 Greenfield-crescent, Edgbaston, Birmingham.
1887. §Godlee, Francis. 51 Portland-street, Manchester.

Year of Election.

1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1880. ‡Godman, F. Du Cane, F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, London, W.
1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. §Godwin-Austen, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1886. §Goldsmid, Major-General Sir F. J., C.B., K.C.S.I., F.R.G.S. 3 Observatory-avenue, London, W.
1881. ‡Goldschmidt, Edward. Nottingham.
1887. §Goldschmidt, Philip. Oldenburg House, Rusholme, Manchester.
1873. ‡Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.
1884. ‡Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1878. ‡Good, Rev. Thomas, B.D. 51 Wellington-road, Dublin.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1886. ‡Goodman, F. B. 46 Wheeley's-road, Edgbaston, Birmingham.
1885. ‡Goodman, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡Goodman, Neville, M.A. Peterhouse, Cambridge.
1884. §Goodridge, Richard E. W. Box No. 382, Post Office, Winnipeg, Canada.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1883. ‡Goouch, B., B.A. 2 Oxford-road, Birkdale, Southport.
1885. ‡Gordon, General the Hon. Sir Alexander Hamilton. 50 Queen's Gate-gardens, London, S.W.
1885. §Gordon, Rev. Cosmo, D.D., F.R.A.S., F.G.S. Chetwynd Rectory, Newport, Salop.
1885. ‡Gordon, Rev. George, LL.D. Birnie, by Elgin, N.B.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. Fernhill, Henbury, near Bristol.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1885. §Gordon, Rev. William. Braemar, N.B.
1887. §Gordon, William John. 21 Catherstone-terrace, London, S.W.
1865. ‡Gore, George, LL.D., F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1875. *Gotch, Francis, B.A., B.Sc. Holywell Cottage, Oxford.
*Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
*Gotch, Thomas Henry. Kettering.
1873. §Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. St. Helen's, Booterstown, Dublin.
1881. ‡Gough, Thomas, B.Sc., F.C.S. Elmfield College, York.
1868. ‡Gould, Rev. George. Unthank-road, Norwich.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill, Glasgow.
Gowland, James. London-wall, London, E.C.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.

Year of Election.

1886. §Grabham, Michael C., M.D. Madeira.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *GRAHAM, CYRIL, C.M.G., F.L.S., F.R.G.S. Travellers' Club, Pall Mall, London, S.W.
1875. ‡GRAHAME, JAMES. 12 St. Vincent-street, Glasgow.
1852. *GRAINGER, Rev. Canon JOHN, D.D., M.R.I.A. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.
1870. ‡GRANT, Colonel JAMES A., C.B., C.S.I., F.R.S., F.L.S., F.R.G.S. 19 Upper Grosvenor-street, London, W.
1855. *GRANT, ROBERT, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1854. ‡GRANTHAM, RICHARD B., M.Inst.C.E., F.G.S. Northumberland-chambers, Northumberland-avenue, London, W.C.
1864. ‡Grantham, Richard F. Northumberland-chambers, Northumberland-avenue, London, W.C.
1887. §Gratrix, Samuel. Alport Town, Manchester.
1881. ‡Graves, E. 22 Trebovir-road, Earl's Court-road, London, S.W.
1887. §Graves, John. Broomhurst, Eccles Old-road, Manchester.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Worksop.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1887. §Gray, Joseph W., F.G.S. Spring Hill, Wellington-road South, Stockport.
1887. §Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. §Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1881. ‡Gray, Thomas. The University, Glasgow.
1883. ‡Gray, Thomas. Spital Hill, Morpeth.
1873. ‡Gray, William, M.R.I.A. 8 Mount Charles, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. 36 Gutter-lane, London, E.C.
1883. ‡Gray, Mrs. W. L. 36 Gutter-lane, London, E.C.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1883. §Greathead, J. H. 8 Victoria-chambers, London, S.W.
1866. §Greaves, Charles Augustus, M.B., LL.B. 101 Friar-gate, Derby.
1887. §Greaves, H. R. The Orchards, Mill End, Stockport.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 3 South-square, Gray's Inn, London, W.C.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1879. ‡Green, A. F. 15 Ashwood-villas, Headingley, Leeds.
1887. §Green, Frieze, 34 Gay-street, Bath.
1887. §Greenhalgh, Richard. 1 Temple-gardens, The Temple, London, E.C.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1882. ‡GREENHILL, A. G., M.A., Professor of Mathematics at the Royal Artillery Institution, Woolwich. Emmanuel College, Cambridge.
1881. §Greenhough, Edward. Matlock Bath, Derbyshire.
1884. ‡Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, London, N.W.
1884. ‡Greenshields, E. B. Montreal, Canada.
1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. §Greenwell, G. C., jun. Poynton, near Stockport.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1875. ‡Greenwood, Frederick. School of Medicine, Leeds.
1862. *Greenwood, Henry. 32 Castle-street, and the Woodlands, Anfield-road, Anfield, Liverpool.

Year of
Election.

1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1883. ‡GREENWOOD, J. G., LL.D., Vice-Chancellor of Victoria University. Owens College, Manchester.
1849. ‡Greenwood, William. Stones, Todmorden.
1887. §Greenwood, Professor W. H., C.E. Firth College, Sheffield.
1887. *Greg, Arthur. Eagley, near Bolton, Lancashire.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 12 Alexandra-road, Finsbury Park, London, N.
1860. ‡GREGOR, Rev. WALTER, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Sir Charles Hutton, K.C.M.G., M.Inst.C.E. 2 Delahay-street, Westminster, S.W.
1883. ‡Gregson, Edward, Ribble View, Preston.
1883. ‡Gregson, G. E. Ribble View, Preston.
1861. *Gregson, Samuel Leigh. Aigburth-road, Liverpool.
1881. ‡Gregson, William. Baldersby, Thirsk.
1875. ‡Grenfell, J. Granville, B.A., F.G.S. 5 Albert-villas, Clifton, Bristol.
1875. ‡*Grey, Mrs. Maria G.* 18 *Cadogan-place, London, S.W.*
1871. *Grierson, Samuel, Medical Superintendent of the District Asylum, Melrose, N.B.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfriesshire.
1875. ‡Grieve, David, F.R.S.E., F.G.S. Lockharton-gardens, Slateford, Edinburgh.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1859. *GRIFFITH, GEORGE, M.A., F.C.S. Harrow.
1870. ‡Griffith, Rev. Henry, F.G.S. Brooklands, Isleworth, Middlesex.
1884. ‡Griffiths, E. H. 12 Park-side, Cambridge.
1884. ‡Griffiths, Mrs. 12 Park-side, Cambridge.
1847. ‡Griffiths, Thomas. Bradford-street, Birmingham.
1879. §Griffiths, Thomas, F.C.S., F.S.S. Heidelberg House, King's-road, Clapham Park, London, S.W.
1875. ‡Grignon, James, H.M. Consul at Riga. Riga.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1881. ‡Gripper, Edward. Nottingham.
1864. ‡GROOM-NAPIER, CHARLES OTTLEY. 18 Elgin-road, St. Peter's Park, London, N.W.
GROVE, The Hon. Sir WILLIAM ROBERT, Knt., M.A., D.C.L., LL.D., F.R.S. 115 Harley-street, London, W.
1863. *GROVES, THOMAS B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. 141 Leinster-road, Rathmines, Dublin.
1886. §Grundy, John. Park Drive, Nottingham.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
1887. §GUILLEMARD, F. H. H. Eltham, Kent.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1862. ‡Gunn, John, M.A., F.G.S. 82 Prince of Wales-road, Norwich.
1885. ‡Gunn, John. Dale, Halkirk, Caithness.
1877. ‡Gunn, William, F.G.S. Office of the Geological Survey of Scotland, Sheriff's Court House, Edinburgh.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, South Kensington, London, S.W.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1868. *Gurney, John. Sprouston Hall, Norwich.

Year of Election.

1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1883. ‡Guthrie, Malcolm. 2 Parkfield-road, Liverpool.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡GWYTHER, R. F., M.A. Owens College, Manchester.

1884. ‡Haanel, E., Ph.D. Cobourg, Ontario, Canada.
1887. §Hackett, Henry Eugene. Hyde-road, Gorton, Manchester.
1865. ‡Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *HADDON, ALFRED CORT, B.A., F.Z.S., Professor of Zoology in the Royal College of Science, Dublin.
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1888. *Hadfield, R. A. Hecla Works, Sheffield.
1870. ‡*Hadivan, Isaac. 3 Huskisson-street, Liverpool.*
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1879. ‡HAKE, H. WILSON, Ph.D., F.C.S. Queenwood College, Hants.
1875. ‡Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1887. §Hale, The Hon. E. J. 9 Mount-street, Manchester.
1883. ‡Haliburton, Robert Grant. National Club, Whitehall, London, S.W.
1872. ‡Hall, Dr. Alfred. 8 Mount Ephraim, Tunbridge Wells.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. *Hall, Miss Emily. 24 Scarisbrick-street, Southport.
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, London, W.C.
1854. *HALL, HUGH FERGIE, F.G.S. Sunnyside, Wavertree, Liverpool.
1887. §Hall, John. Springbank, Leftwich, Northwich.
1872. *Hall, Captain Marshall, F.G.S. St. John's, Bovey Tracey, South Devon.
1885. §Hall, Samuel. 19 Aberdeen Park, Highbury, London, N.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. ‡Hall, Walter. 11 Pier-road, Erith.
1883. *Hall, Miss Wilhelmina. The Gore, Eastbourne.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1868. *HALLETT, WILLIAM HENRY, F.L.S. Buckingham House, Marine Parade, Brighton.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1886. §Hambleton, G. W. 76 Upper Gloucester-place, London, N.W.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Holmeside, Hazelwood, Derby.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 1A Albyn-place, Aberdeen.
1869. ‡Hamilton, Rowland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1881. *Hammond, Robert. Hilldrop, Highgate, London, N.
1878. ‡Hanagan, Anthony. Luckington, Dalkey.
1878. §Hance, Edward M., LL.B. 6 Sea Bank-avenue, Egremont, Cheshire.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, London, S.W.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, London, N.

Year of
Election.

1857. ‡Hancock, William J. 23 Synnot-place, Dublin.
1847. ‡HANCOCK, W. NEILSON, LL.D., M.R.I.A. 64 Upper Gardiner-street, Dublin.
1876. ‡Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1865. ‡*Hands, M. Coventry.*
1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. §Hannaford, E. C. 1591 Catherine-street, Montreal, Canada.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1886. §Hansford, Charles. 3 Alexandra-terrace, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., LL.D., F.R.S., F.C.S. (GENERAL SECRETARY.) Cowley Grange, Oxford.
1886. *Hardcastle, Basil W., F.S.S. Beechenden, Hampstead, London, N.W.
1884. *Hardcastle, Norman C., M.A., LL.M. Downing College, Cambridge.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrooke House, Exeter.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1886. ‡Hardman, John B. St. John's, Hunter's-lane, Birmingham.
1872. ‡*Hardwicke, Mrs. 192 Piccadilly, London, W.*
1880. ‡Hardy, John. 118 Embden-street, Manchester.
1838. *HARE, CHARLES JOHN, M.D. Berkeley House, 15 Manchester-square, London, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. §Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1876. ‡Harker, Allen, F.L.S., Professor of Natural History in the Royal Agricultural College, Cirencester.
1887. §Harker, T. H. Brook House, Fallowfield, Manchester.
1878. *Harkness, H. W. California Academy of Sciences, San Francisco, California, U.S.A.
1871. ‡Harkness, William, F.C.S. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton, Sussex.
1883. *Harley, Miss Clara. 4 Wellington-square, Oxford.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, London, W.C.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. 4 Wellington-square, Oxford.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., B.Sc. King's College, Cambridge.
1882. ‡Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. ‡Harrington, B. J., B.A., Ph.D., Professor of Chemistry and Mineralogy in McGill University, Montreal. Wallbrac-place, Montreal, Canada.
1872. *Harris, Alfred. Lunefield, Kirkby-Lonsdale, Westmoreland.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
1842. *Harris, G. W., M.Inst.C.E. Mount Gambier, South Australia.
1884. §Harris, Miss Katherine E. 73 Albert Hall Mansions, Kensington-gore, London, S.W.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.

Year of Election.

1864. ‡Harrison, George. Barnsley, Yorkshire.
1873. ‡*Harrison, George, Ph.D., F.L.S., F.C.S.* 96, *Northgate, Huddersfield.*
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *HARRISON, JAMES PARK, M.A. 22 Connaught-street, Hyde Park, London, W.
1870. ‡HARRISON, REGINALD. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1883. ‡Harrison, Thomas. 34 Ash-street, Southport.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1886. §Harrison, William. The Horsehills, Wolverhampton.
1886. ‡Harrison, W. Jerome, F.G.S. 365 Lodge-road, Hockley, Birmingham.
1854. ‡Harrowby, The Right Hon. the Earl of. 39 Grosvenor-square, London, W.; and Sandon Hall, Lichfield.
1885. ‡HART, CHARLES J. 10 Calthorpe-road, Edgbaston, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1881. §Hart, Thomas, F.G.S. Yewbarrow, Grange-over-Sands, Carnforth.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
Hartley, James. Sunderland.
1871. ‡HARTLEY, WALTER NOEL, F.R.S. L. & E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin.
1886. §HARTOG, Professor M. M., D.Sc. Queen's College, Cork.
1887. §Hartog, P. J., B.Sc. 5 Portsdown-road North, London, W.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
1885. ‡Harvey, Surgeon Major Robert, M.D. Calcutta.
1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1882. ‡Haslam, George James, M.D. Owens College, Manchester.
1875. ‡HASTINGS, G. W., M.P. Barnard's Green House, Malvern.
1886. ‡Hatherton, The Right Hon. Lord, C.B. Haws Hall, Birmingham.
1857. ‡HAUGHTON, Rev. SAMUEL, M.A., M.D., D.C.L., LL.D., F.R.S., M.R.I.A., F.G.S., Senior Fellow of Trinity College, Dublin. Dublin.
1874. ‡Hawkins, B. Waterhouse, F.G.S. Century Club, East Fifteenth-street, New York, U.S.A.
1887. *Hawkins, William. 11 Fountain-street, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, London, S.W.
*HAWKSHAW, Sir JOHN, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. 50 Harrington-gardens, South Kensington, S.W.; and 33 Great George-street London, S.W.
1868. §HAWKSLEY, THOMAS, M.Inst.C.E., F.R.S., F.G.S. 30 Great George-street, London, S.W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1887. §Haworth, S. E. Warsley-road, Swinton, Manchester.
1886. ‡Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1877. ‡Hay, Arthur J. Lerwick, Shetland.

Year of Election.

1861. *HAY, Admiral the Right Hon. Sir JOHN C. D., Bart., K.C.B., D.C.L., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1885. *Haycraft, Professor John Berry, M.B., B.Sc., F.R.S.E. Physiological Laboratory, the University, Edinburgh.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1869. ‡Hayward, J. High-street, Exeter.
1858. *HAYWARD, ROBERT BALDWIN, M.A., F.R.S. Fishers, Harrow.
1879. *Hazlehurst, George S. Rhyl, North Wales.
1851. §HEAD, JEREMIAH, M.Inst.C.E., F.C.S. Middlesbrough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. §Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1871. §Healey, George. Brantfield, Bowness, Windermere.
1883. *Heap, Ralph, jun. 1 Brick-court, Temple, London, E.C.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1883. ‡*Heape, Charles. 14 Hawkshead-street, Southport.*
1883. ‡Heape, Joseph R. 96 Tweedale-street, Rochdale.
1882. *Heape, Walter. Royal Western Yacht Club, Plymouth.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1877. ‡Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Calton Hill, Edinburgh.
1861. ‡HEATHFIELD, W. E., F.C.S., F.R.G.S., F.R.S.E. 1 Powis-grove, Brighton; and Arthur's Club, St. James's, London, S.W.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1886. ‡Heaton, C. W. Tower House, Belvedere, Kent.
1886. §Heaton, Miss Ellen. Woodhouse-square, Leeds.
1865. ‡Heaton, Harry. Harborne House, Harborne, near Birmingham.
1884. §Heaviside, Rev. George, B.A., F.R.G.S. The Hollies, Stoke Green, Coventry.
1833. ‡HEAVISIDE, Rev. Canon J. W. L., M.A. The Close, Norwich.
1855. ‡HECTOR, Sir JAMES, K.C.M.G., M.D., F.R.S., F.G.S., F.R.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡Heddle, M. Forster, M.D., F.R.S.E. St. Andrews, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1882. ‡Hedger, Philip. Cumberland-place, Southampton.
1887. §Hedges, Killingworth. 25 Queen Anne's-gate, London, S.W.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1887. §Hembry, Frederick William, F.R.M.S. Sussex Lodge, Sidcup, Kent.
1867. ‡Henderson, Alexander. Dundee.
1873. *Henderson, A. L. 16 Lee-road, Blackheath, London, S.E.
1883. §Henderson, Mrs. A. L. 16 Lee-road, Blackheath, London, S.E.
1880. *Henderson, Captain W. H., R.N. 21 Albert Hall Mansions, London, S.W.
1876. *Henderson, William. Williamfield, Irvine, N.B.
1885. ‡Henderson, William. Devanha House, Aberdeen.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland. Brookvale, Donnybrook, Co. Dublin.
1857. ‡Hennessy, Sir John Pope, K.C.M.G., Governor and Commander-in-Chief of Mauritius.

Year of
Election.

1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S., Professor of Mechanics and Mathematics in the City and Guilds of London Institute. Central Institution, Exhibition-road, London, S.W.
Henry, Franklin. Portland-street, Manchester.
1873. Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell. Stratheden House, Hyde Park, London, W.
*HENRY, WILLIAM CHARLES, M.D., F.R.S., F.G.S., F.R.G.S., F.C.S. Haffield, near Ledbury, Herefordshire.
1884. ‡Henshaw, George H. 43 Victoria-street, Montreal, Canada.
1870. ‡Henty, William. 12 Medina-villas, Brighton.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Dartford, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Monkbridge, Robinhood-lane, Sutton, Surrey.
1887. *Herdman, William A., D.Sc., Professor of Natural History in University College, Liverpool.
1871. *HERSCHEL, Professor ALEXANDER S., M.A., D.C.L., F.R.S., F.R.A.S. College of Science, Newcastle-on-Tyne.
1883. ‡Herschel, Miss F. Collingwood, Hawkhurst, Kent.
1874. §HERSCHEL, Lieut.-Colonel JOHN, R.E., F.R.S., F.R.A.S. Collingwood, Hawkhurst, Kent.
1883. ‡Hesketh, Colonel E. Fleetwood. Meol's Hall, Southport.
1884. §Hewett, George Edwin. The Leasowe, Cheltenham.
1883. §Hewson, Thomas. Care of J. C. C. Payne, Esq., Botanic-avenue, The Plains, Belfast.
1881. ‡Hey, Rev. William Croser, M.A. Clifton, York.
1882. §Heycock, Charles T., B.A. King's College, Cambridge.
1883. §Heyes, John Frederick, M.A., F.C.S., F.R.G.S. 9 King-street, Oxford; and 5 Rufford-road, Fairfield, Liverpool.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1879. ‡Heywood, A. Percival. Duffield Bank, Derby.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
1886. §Heywood, Henry. Cardiff.
*HEYWOOD, JAMES, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1861. *HEYWOOD, OLIVER, J.P., D.L. Claremont, Manchester.
1887. §Heywood, Robert. Mayfield, Victoria Park, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1881. §Hick, Thomas, B.A., B.Sc. Brighton-grove, Rusholme, Manchester.
1875. ‡HICKS, HENRY, M.D., F.R.S., F.G.S. Hendon Grove, Hendon, Middlesex, N.W.
1877. §HICKS, Professor W. M., M.A., F.R.S., Principal of Firth College, Sheffield. Firth College, Sheffield.
1886. §Hicks, Mrs. W. M. 18 Newbould-lane, Broomhill, Sheffield.
1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.
1887. *Hickson, Sydney J., M.A. Downing College, Cambridge.
1864. *HIERN, W. P., M.A. Castle House, Barnstaple.
1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.
1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.
1871. ‡HIGGINS, CLEMENT, B.A., F.C.S. 103 Holland-road, Kensington, London, W.
1854. ‡HIGGINS, Rev. HENRY H., M.A. The Asylum, Rainhill, Liverpool.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
1885. *Hill, Alexander, M.A., M.B. Grantchester, near Cambridge.
Hill, Arthur. Bruce Castle, Tottenham, Middlesex.
1880 ‡Hill, Benjamin. Cwmdwr, near Clydach, Swansea.

Year of
Election.

1883. §Hill, Berkeley, M.B., Professor of Clinical Surgery in University College, London. 66 Wimpole-street, London, W.
1872. §Hill, Charles, F.S.A. Rockhurst, West Hoathley, East Grinstead.
1881. §HILL, Rev. EDWIN, M.A., F.G.S. St. John's College, Cambridge.
1887. §Hill, G. H. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1857. §Hill, John, M.Inst.C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1871. ‡*Hill, Lawrence. The Knowe, Greenock.*
1886. ‡Hill, M. J. M. 16 Pembury-road, Lower Clapton, London, E.
1881. ‡Hill, Pearson. 50 Belsize Park, London, N.W.
1872. *Hill, Rev. Canon, M.A., F.G.S. Sheering Rectory, Harlow.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *HILLHOUSE, WILLIAM, M.A., Professor of Botany in Mason Science College, Birmingham. 95 Harborne-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. *Hills, Thomas Hyde. 225 Oxford-street, London, W.
1887. §Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Stancliff House, Clevedon, Somerset.
1870. ‡HINDE, G. J., Ph.D., F.G.S. Avondale-road, Croydon, Surrey.
1883. *Hindle, James Henry. 67 Avenue-parade, Accrington.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1886. ‡Hingley, Benjamin, M.P. Hatherton Lodge, Cradley, Worcestershire.
1881. ‡Hingston, J. T. Clifton, York.
1884. ‡HINGSTON, WILLIAM HALES, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1861. *HIRST, T. ARCHER, Ph.D., F.R.S., F.R.A.S. 7 Oxford and Cambridge Mansions, Marylebone-road, London, N.W.
1870. ‡Hitchman, William, M.D., LL.D., F.L.S. 144 Phythian-street, Low Hill, Liverpool.
1884. ‡Hoadrey, John Chipman. Boston, Massachusetts, U.S.A.
Hoare, J. Gurney. Hampstead, London, N.W.
1881. §Hobbes, Robert George. Livingstone House, 374 Wandsworth-road, London, S.W.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1879. §Hobkirk, Charles P., F.L.S. West Riding Union Bank, Dewsbury.
1887. *Hobson, Bernard, B.Sc. Tapton Elms, Sheffield.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1879. §Hobson, John. Tapton Elms, Sheffield.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1883. ‡Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *HODGKIN, THOMAS. Benwell Dene, Newcastle-on-Tyne.

Year of Election.

1887. *Hodgkinson, Alexander. 18 St. John-street, Manchester.
1880. ‡Hodgkinson, W. R. Eaton, Ph.D. Science Schools, South Kensington Museum, London, S.W.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1873. ‡*Hodgson, James. Oakfield, Manningham, Bradford, Yorkshire.*
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-on-Tyne.
1865. *HOFMANN, AUGUST WILHELM, M.D., LL.D., Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
1854. *Holcroft, George. Tyddyn-Gwladis, Ganllwyd, near Dolgelly, North Wales.
1883. ‡Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1873. *Holden, Isaac, M.P. Oakworth House, near Keighley, Yorkshire.
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.
1857. *Holder, Henry William. Owens College, Manchester.
1887. *Holdsworth, C. J. Wilmslow, Cheshire.
1879. ‡Holland, Calvert Bernard. Ebbw Vale, South Wales.
*Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, London, N.W.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1865. ‡Holliday, William. New-street, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring-grove, Isleworth, Middlesex.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.
1882. *Holmes, Thomas Vincent, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1876. ‡*Holms, Colonel William, M.P. 95 Cromwell-road, South Kensington, London, S.W.*
1887. §Holt, Thomas. Atlas Iron Works, Molesworth-street, Rochdale.
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
1875. *Hood, John. The Elms, Cotham Hill, Bristol.
1847. ‡HOOKER, Sir JOSEPH DALTON, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S. The Camp, Sunningdale.
1865. *Hooper, John P. Coventry Park, Streatham, London, S.W.
1877. *Hooper, Rev. Samuel F., M.A. 39 Lorrimore-square, London, S.E.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. 14 Arlie-gardens, Campden Hill, London, W.
1884. *Hopkins, Edward M. 3 Upper Berkeley-street, Portman-square, London, W.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1884. *HOPKINSON, CHARLES. 29 Princess-street, Manchester.
1882. *Hopkinson, Edward, D.Sc. Ireton Bank, Platt-lane, Rusholme, Manchester.
1870. *HOPKINSON, JOHN, M.A., D.Sc., F.R.S. 3 Holland Villas-road, Kensington, London, W.
1871. *HOPKINSON, JOHN, F.L.S., F.G.S., F.R.Met.Soc. 95 New Bond-street, London, W.; and The Grange, St. Albans.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1886. §Horne, Edward H. Innisfail, Beulah Hill, Norwood, S.E.
1885. ‡Horne, John, F.R.S.E., F.G.S. 41 Southside-road, Inverness.

Year of
Election.

1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J., F.R.G.S., F.L.S. Surrey Mount, Forest Hill, London, S.E.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. §Horsfall, T. C. Bollin Tower, Alderley Edge, Chester.
1856. ‡Horsley, John H. 1 Ormond-terrace, Cheltenham.
1884. *Hotblach, G. S. Prince of Wales-road, Norwich.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1886. ‡Houghton, F. T. S., M.A. 119 Gough-road, Edgbaston, Birmingham.
1887. §Houldsworth, Sir W. H., Bart., M.P., Norbury Booths, Knutsford.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
1884. ‡Houston, William. Legislative Library, Toronto, Canada.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.
Hovenden, W. F., M.A. Bath.
1879. *Howard, D. 60 Belsize Park, London, N.W.
1883. §Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.
1886. §Howard, James L., B.Sc. 20 Oxford-road, Waterloo, near Liverpool.
1887. *Howard, S. S, Llanishen Rise, near Cardiff.
1882. ‡Howard, William Frederick, Assoc.M.Inst.C.E. 13 Cavendish-street, Chesterfield, Derbyshire.
1883. ‡Howarth, Richard. York-road, Birkdale, Southport.
1886. ‡Howatt, David. 3 Birmingham-road, Dudley.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1885. §Howden, James C., M.D. Sunnyside, Montrose, N.B.
1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh.
1887. §Howell, J. A. Edward-street, Werneth, Oldham.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1886. §Howes, Professor G. B., F.L.S. Science Schools, South Kensington, London, S.W.
1884. ‡Howland, Edward P., M.D. 211 $41\frac{1}{2}$-street, Washington, U.S.A.
1884. ‡Howland, Oliver Aiken. Toronto, Canada.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡Howorth, H. H., M.P., F.S.A. Derby House, Eccles, Manchester.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1883. ‡Hoyle, James. Blackburn.
1883. ‡Hoyle, William. Claremont, Bury, Lancashire.
1887. §Hoyle, William E., M.A. 32 Queen-street, Edinburgh.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1879. ‡Hudson, Robert S., M.D. Redruth, Cornwall.
1883. ‡*Hudson, Rev. W. C. 58 Belmont-street, Southport.*
1867. *Hudson, William H. H., M.A., Professor of Mathematics in King's College, London. 15 Altenburg-gardens, Clapham Common, London, S.W.
1858. *Huggins, William, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse Hill, Brixton, London, S.W.
1857. ‡Huggon, William. 30 Park-row, Leeds.
1887. §Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. ‡Hughes, Miss E. P. Newnham College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.

Year of Election.

1887. §Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1876. *Hughes, Rev. Thomas Edward. Wallfield House, Reigate.
1868. §HUGHES, T. M'K., M.A., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1883. ‡HULKE, JOHN WHITAKER, F.R.S., F.R.C.S., F.G.S. 10 Old Burlington-street, London, W.
1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S., Director of the Geological Survey of Ireland and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1887. *Hummel, Professor J. J. Yorkshire College, Leeds.
1884. *Humphreys, A. W. 45 William-street, New York, U.S.A.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *HUMPHRY, GEORGE MURRAY, M.D., F.R.S., Professor of Surgery in the University of Cambridge. Grove Lodge, Cambridge.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1884. ‡HUNT, T. STERRY, M.A., D.Sc., LL.D., F.R.S. 105 Union-avenue, Montreal, Canada.
1864. ‡Hunt, W. Folkestone.
1875. *Hunt, William. Northcote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. 4 Westmoreland-road, Newcastle-on-Tyne.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1884. *Hunter, Michael, jun. Greystones, Sheffield.
1869. *Hunter, Rev. Robert. LL.D., F.G.S. Forest Retreat, Staples-road, Loughton, Essex.
1879. ‡HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, London. King's College, London, W.C.
1885. ‡Huntly, The Right Hon. the Marquis of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1883. *Hurst, Charles Herbert. Owens College, Manchester.
1869. ‡Hurst, George. Bedford.
1882. ‡Hurst, Walter, B.Sc. West Lodge, Todmorden.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. May Bank, Bournemouth.
1887. §Husband, W. E. 56 Bury New-road, Manchester.
1882. ‡Hussey, Captain E. R., R.E. 24 Waterloo-place, Southampton.
1876. ‡Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.
1868. *Hutchison, Robert, F.R.S.E. 29 Chester-street, Edinburgh.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, London, N.W.
1857. ‡Hutton, Henry D. 17 Palmerston-road, Dublin.
1887. §Hutton, J. A. 29 Dale-street, Manchester.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1852. ‡HUXLEY, THOMAS HENRY, Ph.D., LL.D., D.C.L., F.R.S., F.L.S., F.G.S. 4 Marlborough-place, London, N.W.

Year of Election.

Hyde, Edward. Dukinfield, near Manchester.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

1882. *I'Anson, James, F.G.S. Fairfield House, Darlington.
Ihne, William, Ph.D. Heidelberg.
1873. ‡*Ikin, J. I. 19 Park-place, Leeds.*
1861. ‡Iles, The Ven. Archdeacon, M.A. The Close, Lichfield.
1884. §Iles, George. Windsor Hotel, Montreal, Canada.
1885. ‡im-Thurn, Everard F. British Guiana.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1871. ‡INGLIS, The Right Hon. JOHN, D.C.L., LL.D., Lord Justice-General of Scotland. Edinburgh.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1883. ‡*Ingram, Rev. D. C. Church-street, Southport.*
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Librarian to the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. §Innes, John. The Limes, Alcester-road, Moseley, Birmingham.
1882. §Irving, Rev. A., B.A., B.Sc., F.G.S. Wellington College, Wokingham, Berks.
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, London, W.
1887. §Ito, Tokutaro. 14 Masagochio, Hongo, Tokio, Japan.
1886. ‡Izod, William. Church-road, Edgbaston, Birmingham.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. ‡Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. ‡JACKSON, A. H. College of Pharmacy, Melbourne, Australia.
1879. ‡Jackson, Arthur, F.R.C.S. Wilkinson-street, Sheffield.
1883. ‡Jackson, Mrs. Esther. 16 East Park-terrace, Southampton.
1883. ‡Jackson, Frank. 11 Park-crescent, Southport.
1883. *Jackson, F. J. 1 Morley-road, Southport.
1883. ‡Jackson, Mrs. F. J. 1 Morley-road, Southport.
1874. *Jackson, Frederick Arthur. Belmont, Lyme Regis, Dorset.
1886. §Jackson, George. Clareen, Higher Warberry, Torquay.
1887. *Jackson, George. 53 Elizabeth-street, Cheetham, Manchester.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 15 The Terrace, High-road, Lewisham, S.E.
1869. §Jackson, Moses. The Vale, Ramsgate.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, The Grove, New Wimbledon, Surrey.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1874. *Jaffe, John. Edenvale, Strandtown, near Belfast.
1865. *Jaffray, John. Park-grove, Edgbaston, Birmingham.
1872. ‡James, Christopher. 8 Laurence Pountney-hill, London, E.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1886. §James, Frank. Portland House, Aldridge, near Walsall.
1886. *James, Harry Berkeley, F.R.G.S. 16 Ashburn-place, London, S.W.
1863. *JAMES, Sir WALTER, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1884. §James, W. Culver, M.D. 11 Marloes-road, London, W.
1858. ‡James, William C. Woodside, Plymouth.
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, London, W.

Year of Election.

1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1887. §Jamieson, G. Auldjo. 3 Drumsheugh-gardens, Edinburgh.
1885. ‡Jamieson, Patrick. Peterhead, N.B
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1886. *James, Harry Berkeley, F.R.G.S. 16 Ashburn-place, London, S.W.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
1870. ‡Jarrold, John James. London-street, Norwich.
1886. §Jeffcock, Rev. John Thomas. The Rectory, Wolverhampton.
1856. §JEFFERY, HENRY M., M.A., F.R.S. 9 Dunstanville-terrace, Falmouth.
1855. *Jeffray, John. Winton House, Kelvinside, Glasgow.
1883. ‡Jeffreys, Miss Gwyn. 1 The Terrace, Kensington, London, W.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. Pump-court, Temple, London, E.C.
1885. §Jeffreys, Dr. Richard Parker. Eastwood House, Chesterfield.
1852. ‡JELLETT, Rev. JOHN H., D.D., D.C.L., M.R.I.A., Provost of Trinity College, Dublin.
1881. §JELLICOE, C. W. A. Southampton.
1864. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1873. §Jenkins, Major-General J. J. 16 St. James's-square, London, S.W.
1880. *JENKINS, Sir JOHN JONES. The Grange, Swansea.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. 13 Victoria-street, London, S.W.
1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.
Jessop, William, jun. Overton Hall, Ashover, Chesterfield.
1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. §Johnson, Alexander, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.
1883. ‡Johnson, Ben. Micklegate, York.
1871. *Johnson, David, F.C.S., F.G.S. 52 Fitzjohn's-avenue, South Hampstead, London, N.W.
1881. ‡Johnson, Major E. Cecil. Junior United Service Club, Charles-street, London, S.W.
1883. ‡Johnson, Edmund Litler. 73 Albert-road, Southport.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1875. ‡Johnson, James Henry, F.G.S. 73 Albert-road, Southport.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1870. ‡Johnson, Richard C., F.R.A.S. 19 Catherine-street, Liverpool.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Samuel George. Municipal Offices, Nottingham.
1887. §Johnson, W. H. Woodleigh, Altrincham, Cheshire.
1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.
1883. ‡Johnson, William. Harewood, Roe-lane, Southport.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1883. ‡Johnston, H. H. Tudor House, Champion Hill, London, S.E.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.

Year of Election.

1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883. §Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appele, N.W. Territory, Canada.
1884. *Johnston, W. H. 6 Latham-street, Preston, Lancashire.
1885. ‡Johnston-Lavis, H. J., M.D., F.G.S. Palazzo Caramanico, Chiatomone, Naples.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1864. *Johnstone, James. Alva House, Alva, by Stirling, N.B.
1864. ‡*Johnstone, John. 1 Barnard-villas, Bath.*
1876. ‡Johnstone, William. 5 Woodside-terrace, Glasgow.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. ‡JOLLY, WILLIAM, F.R.S.E., F.G.S., H.M. Inspector of Schools. St. Andrew's-road, Pollokshields, Glasgow.
1881. ‡Jones, Alfred Orlando, M.D. Cardigan Villa, Harrogate.
1849. ‡Jones, Baynham. Walmer House, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
1887. §Jones, D. E., B.Sc. University College, Aberystwith.
1887. §Jones, Francis. Beaufort House, Alexandra Park, Manchester.
1883. *Jones, George Oliver, M.A. 5 Cook-street, Liverpool.
1884. §Jones, Rev. Harry, M.A. Savile Club, Piccadilly, London, W.
1877. ‡Jones, Henry C., F.C.S. Normal School of Science, South Kensington, London, S.W.
1883. ‡Jones, Rev. Canon Herbert. Waterloo, Liverpool.
1881. ‡Jones, J. Viriamu, M.A., B.Sc., Principal of the University College of South Wales and Monmouthshire. Cardiff.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. 10 Uverdale-road, King's-road, Chelsea, London, S.W.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1875. *Jose, J. E. 11 Cressington Park, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1875. *Joule, Benjamin St. John B., J.P. 12 Wardle-road, Sale, near Manchester.
1842. *JOULE, JAMES PRESCOTT, LL.D., F.R.S., F.C.S. 12 Wardle-road, Sale, near Manchester.
1847. ‡JOWETT, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1858. ‡Jowett, John. Leeds.
1879. ‡Jowitt, A. Hawthorn Lodge, Clarkehouse-road Sheffield.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.
1848. *Joy, Rev. Charles Ashfield. West Hanney, Wantage, Berkshire.
1883. §Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. §Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1848. *Jubb, Abraham. Halifax.
1870. ‡JUDD, JOHN WESLEY, F.R.S., Pres. G.S., Professor of Geology in the Royal School of Mines. Hurstleigh, Kew.
1883. ‡Justice, Philip M. 14 Southampton-buildings, Chancery-lane, London, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 8 Osborne-road, Stroud Green-road, London, N.
KANE, Sir ROBERT, M.D., LL.D., F.R.S., M.R.I.A., F.C.S. Fortlands, Killiney, Co. Dublin.
1887. §Kay, Miss. Hamerlaund, Broughton Park, Manchester.

Year of Election.

1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.

Kay, John Cunliff. Fairfield Hall, near Skipton.

1883. ‡Kearne, John H. Westcliffe-road, Birkdale, Southport.

1884. ‡Keefer, Samuel. Brockville, Ontario, Canada

1884. ‡Keefer, Thomas Alexander. Port Arthur, Ontario, Canada.

1875. ‡Keeling, George William. Tuthill, Lydney.

1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.

1878. *Kelland, William Henry. 110 Jermyn-street, London, S.W.; and Grettans, Bow, North Devon.

1887. §Kellas-Johnstone, J. F. 69 Princess-street, Manchester.

1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.

1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.

1885. §Keltie, J. Scott, Librarian R.G.S. 1 Savile-row, London, W.

1887. §Kemp, Harry. 254 Stretford-road, Manchester.

1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.

1884. §Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.

1875. ‡KENNEDY, ALEXANDER B. W., F.R.S., M.Inst.C.E., Professor of Engineering in University College, London.

1884. ‡Kennedy, George L., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.

1876. ‡Kennedy, Hugh. Redclyffe, Partickhill, Glasgow.

1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.

1884. §Kennedy, William. Hamilton, Ontario, Canada.

1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.

Kent, J. C. Levant Lodge, Earl's Croome, Worcester.

1886. §Kenward, James, F.S.A. 280 Hagley-road, Birmingham.

1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.

1855. *Ker, Robert. Dougalston, Milngavie, N.B.

1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.

1881. ‡Kermode, Philip M. C. Ramsay, Isle of Man.

1884. ‡Kerr, James, M.D. Winnipeg, Canada.

1887. §Kerr, James. Dunkenhalgh, Accrington.

1883. §Kerr, Dr. John. Garscadden House, near Kilpatrick, Glasgow.

1887. §Kershaw, James. Holly House, Bury New-road, Manchester.

1869. *Kesselmeyer, Charles A. Villa 'Mon Repos,' Altrincham, Cheshire.

1869. *Kesselmeyer, William Johannes. Villa 'Mon Repos,' Altrincham, Cheshire.

1861. *Keymer, John. Parker-street, Manchester.

1883. *Keynes, J. N., M.A., B.Sc., F.S.S. 6 Harvey-road, Cambridge.

1876. ‡Kidston, J. B. West Regent-street, Glasgow.

1886. §Kidston, Robert, F.R.S.E., F.G.S. 24 Victoria-place, Stirling.

1876. ‡Kidston, William. Ferniegair, Helensburgh, N.B.

1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.

1865. *Kinahan, Sir Edward Hudson, Bart, M.R.I.A. 11 Merrion-square North, Dublin.

1878. ‡Kinahan, Edward Hudson, jun. 11 Merrion-square North, Dublin.

1860. ‡KINAHAN, G. HENRY, M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.

1875. *KINCH, EDWARD, F.C.S. Royal Agricultural College, Cirencester.

1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne Park, London, W.

1875. *King, F. Ambrose. Avonside, Clifton, Bristol.

1883. *King, Francis. Thornhill, Penrith.

1871. *King, Rev. Herbert Poole. St. Oswald's College, Ellesmere, Salop.

Year of
Election.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Welford House, Greenhill, Hampstead, London, N.W.
1870. §King, John Thomson. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, London, N.W.
1883. *King, Joseph, jun. Welford House, Greenhill, Hampstead, London, N.W.
1860. *King, Mervyn Kersteman. 1 Vittoria-square, Clifton, Bristol.
1875. *King, Percy L. Avonside, Clifton, Bristol.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1869. ‡Kingdon, K. Taddiford, Exeter.
1861. ‡Kingsley, John. Ashfield, Victoria Park, Manchester.
1876. §Kingston, Thomas. The Limes, Clewer, near Windsor.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1875. §KINGZETT, CHARLES T., F.C.S. Trevena, Amhurst Park, London, N.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Croft Rectory, near Warrington.
1876. *Kirkwood, Anderson, LL.D., F.R.S.E. 7 Melville-terrace, Stirling, N.B.
1875. ‡Kirsop, John. 6 Queen's-crescent, Glasgow.
1883. ‡Kirsop, Mrs. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1881. ‡*Kitching, Langley.* 50 *Caledonian-road, Leeds.*
1886. ‡Klein, Rev. L. Martial. University College, Dublin.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1886. §Knight, J. M. Bushwood, Wanstead, Essex.
1883. ‡Knight, J. R. 32 Lincoln's Inn-fields, London, W.C.
1872. *Knott, George, LL.B., F.R.A.S. Knowles Lodge, Cuckfield, Hayward's Heath, Sussex.
1887. *Knott, Herbert. Wharf Street Mills, Ashton-under-Lyne.
1887. *Knott, John F. Staveleigh, Stalybridge, Yorkshire.
1887. §Knott, Mrs. Staveleigh, Stalybridge, Yorkshire.
1887. §Knott, T. B. Ellerslie, Cheadle Hulme, Cheshire.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡Knowles, James. The Hollies, Clapham Common, S.W.
1870. ‡Knowles, Rev. J. L. 103 Earl's Court-road, Kensington, London, W.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1883. ‡Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.
1883. ‡Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.
1876. ‡Knox, David N., M.A., M.B., 24 Elmbank-crescent, Glasgow.
*Knox, George James. 29 Portland-terrace, Regent's Park, London, N.W.
1875. *Knubley, Rev. E. P. Staveley Rectory, Leeds.
1883. ‡Knubley, Mrs. Staveley Rectory, Leeds.
1881. ‡Kurobe, Hiroo. Legation of Japan, 9 Cavendish-square, London, W.
1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.
1882. ‡*Kyshe, John B.* 19 *Royal-avenue, Sloane-square, London S.W.*

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec, Canada.
1885. *Laing, J. Gerard. 1 Elm-court, Temple, London, E.C.

Year of Election.

1870. ‡Laird, H. H. Birkenhead.
1870. §Laird, John. Grosvenor-road, Claughton, Birkenhead.
1882. ‡Lake, G. A. K., M.D. East Park-terrace, Southampton.
1880. ‡*Lake, Samuel. Milford Docks, Milford Haven.*
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1887. §Lamb, Horace, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. Manchester.
1887. §Lamb, James. Kenwood, Bowdon, Cheshire.
1883. ‡Lamb, W. J. 11 Gloucester-road, Birkdale, Southport.
1883. ‡LAMBERT, Rev. BROOKE, LL.B. The Vicarage, Greenwich, Kent, S.E.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1884. ‡Lancaster, Alfred. Fern Bank, Burnley, Lancashire.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 59 Tresillian-road, St. John's, S.E.
1883. ‡Lang, Rev. Gavin. Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1886. *LANGLEY, J. N., M.A., F.R.S. Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. 11 Wellington Mansions, North Bank, London, N.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Care of Mr. Wheldon, 58 Great Queen-street, Lincoln's Inn-fields, London, W.C.
Lanyon, Sir Charles. The Abbey, White Abbey, Belfast.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1886. ‡Lapraik, W. 9 Malfort-road, Denmark Hill, London, S.E.
1885. §LAPWORTH, CHARLES, LL.D., F.G.S., Professor of Geology and Mineralogy in the Mason Science College, Birmingham. 46 George-road, Edgbaston, Birmingham.
1887. §Larmor, Alexander. Clare College, Cambridge.
1881. ‡Larmor, Joseph, M.A., Professor of Natural Philosophy in Queen's College, Galway.
1883. §Lascelles, B. P. Harrow.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡LAUGHTON, JOHN KNOX, M.A., F.R.G.S. 130 Sinclair-road, West Kensington Park, London, W.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia.
1870. *Law, Channell. Ilsham Dene, Torquay.
1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, London, S.W.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
1884. §Law, Robert. 11 Cromwell-terrace, West Hill Park, Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1885. ‡Lawson, James. 8 Church-street, Huntly, N B.
1857. ‡Lawson, The Right Hon. James A., LL.D., D.C.L., M.R.I.A. 27 Fitzwilliam-street, Dublin.

Year of
Election.

1868. *Lawson, M. Alexander, M.A., F.L.S. Ootâcamund, Bombay.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1875. ‡Leach, Colonel R. E. Mountjoy, Phœnix Park, Dublin.
1883. *Leach, Charles Catterall. Care of Swan & Leach (Limited), 141 Briggate, Leeds.
1883. §Leach, John. Haverhill House, Bolton.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. 6 Sussex-place, Regent's Park, London, N.W.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1847. *LEATHAM, EDWARD ALDAM, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1863. ‡Leavers, J. W. The Park, Nottingham.
1884. *Leavitt, Erasmus Darwin. 604 Main-street, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia.
1883. ‡Lee, Daniel W. Halton Bank, Pendleton, near Manchester.
1861. ‡Lee, Henry, M.P. Sedgeley Park, Manchester.
1883. ‡Lee, J. H. Warburton. Rossall, Fleetwood.
1853. *LEE, JOHN EDWARD, F.G.S., F.S.A. Villa Syracusa, Torquay.
1887. *Lee, Sir Joseph Cooksey. Park Gate, Altrincham.
1884. *Leech, Bosdin T. Oak Mount, Temperley, Cheshire.
1887. §Leech, D. J. Elm House, Whalley Range, Manchester.
1886. *Lees, Lawrence W. Claregate, Tettenhall, Wolverhampton.
1882. ‡Lees, R. W. Moira-place, Southampton.
1859. ‡Lees, William, M.A. St. Leonard's, Morningside-place, Edinburgh.
1883. *Leese, Miss H. K. Fylde-road Mills, Preston, Lancashire.
*Leese, Joseph. Fylde-road Mills, Preston, Lancashire.
1883. ‡Leese, Mrs. Hazeldene, Fallowfield, Manchester.
1881. ‡LE FEUVRE, J. E. Southampton.
1872. ‡LEFEVRE, The Right Hon. G. SHAW, F.R.G.S. 18 Bryanston-square, London, W.
*LEFROY, General Sir JOHN HENRY, R.A., K.C.M.G., C.B., LL.D., F.R.S., F.R.G.S. 82 Queen's-gate, London, S.W.; and Penquite, Par Station, Cornwall.
*Legh, Lieut.-Colonel George Cornwall. High Legh Hall, Cheshire.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡LEICESTER, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1870. ‡Leighton, Andrew. 35 High-park-street, Liverpool.
1886. §Leipner, Adolph, Professor of Botany in University College, Bristol. 47 Hampton Park, Bristol.
1867. ‡Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. ‡Lemon, James, M.Inst.C.E. 11 The Avenue, Southampton.
1863. *LENDY, Major AUGUSTE FREDERIC, F.L.S., F.G.S. Sunbury House Sunbury, Middlesex.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.

Year of Election.

Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1887. *Leon, John F. 17 Mortlake-road, Kew, Surrey.
1871. ‡LEONARD, HUGH, F.G.S., M.R.I.A., F.R.G.S.I. St. David's, Malahide-road, Co. Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1872. ‡*Lermit, Rev. Dr. School House, Dedham.*
1884. §Lesage, Louis. City Hall, Montreal, Canada.
1871. ‡Leslie, Alexander, M.Inst.C.E. 72 George-street, Edinburgh.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1887. §Leverkus, Otto. The Downs, Prestwich, Manchester.
1866. §LEVI, Dr. LEONE, F.S.A., F.S.S., F.R.G.S., Professor of Commercial Law in King's College, London. 5 Crown Office-row, Temple, London, E.C.
1887. *Levinstein, Ivan. Villa Newberg, Victoria Park, Manchester.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, London, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 35 Colebrooke-row, Islington, London, N.
1884. *Lewis, Sir W. T. The Mardy, Aberdare.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1887. §Liebermann, L. 54 Portland-street, Manchester.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1887. *Lightbown, Henry. Weaste Hall, Pendleton, Manchester.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, The Right Rev. CHARLES GRAVES, Lord Bishop of, D.D., F.R.S., M.R.I.A. The Palace, Henry-street, Limerick.
1887. §Limpach, Dr. Crumpsall Vale Chemical Works, Manchester.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. *Lindley, William, M.Inst.C.E., F.G.S. 10 Kidbrooke-terrace, Blackheath, London, S.E.
1870. ‡Lindsay, Thomas, F.C.S. Maryfield College, Maryhill, by Glasgow.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
Lingwood, Robert M., M.A., F.L.S., F.G.S. 6 Park-villas, Cheltenham.
1876. ‡Linn, James. Geological Survey Office, India-buildings, Edinburgh.
1883. §Lisle, H. Claud. Nantwich.
1882. *Lister, Rev. Henry, M.A. Hawridge Rectory, Berkhampstead.
1870. §Lister, Thomas. Victoria-crescent, Barnsley, Yorkshire.
1876. ‡Little, Thomas Evelyn. 42 Brunswick-street, Dublin.
Littledale, Harold. Liscard Hall, Cheshire.
1881. ‡Littlewood, Rev. B. C., M.A. Holmdale, Cheltenham.
1861. *LIVEING, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Cambridge.
1876. *Liversidge, Archibald, F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry and Mineralogy in the University of Sydney, N.S.W. (Care of Messrs. Trübner & Co., Ludgate Hill, London, E.C.)
1864. §Livesay, J. G. Cromartie House, Ventnor, Isle of Wight.
1880. ‡Llewelyn, John T. D. Penllegare, Swansea.
Lloyd, Rev. A. R. Hengold, near Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B., J.P. Edgbaston-grove, Birmingham.

Year of Election.

*Lloyd, George, M.D., F.G.S. 41 York-road, Edgbaston, Birmingham.
1865. ‡Lloyd, John. Queen's College, Birmingham.
1886. ‡Lloyd, John Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Myvod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. 19 Stonebridge Park, Willesden, N.W.
1853. *Locke, John. 133 Leinster-road, Dublin.
1867. *Locke, John. Whitehall Club, London, S.W.
1863. ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. Science Schools, South Kensington, London, S.W.
1886. *Lodge, Alfred, M.A. Cooper's Hill, Staines.
1875. *LODGE, OLIVER J., D.Sc., F.R.S., Professor of Physics in University College, Liverpool. 21 Waverley-road, Sefton Park, Liverpool.
1883. ‡Lofthouse, John. West Bank, Rochdale.
1883. ‡London, Rev. H. High Lee, Knutsford.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1872. ‡Long, Jeremiah. 50 Marine Parade, Brighton.
1871. *Long, John Jex. 11 Doune-terrace, Kelvinside, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1866. ‡Longdon, Frederick. Osmaston-road, Derby.
1883. ‡Longe, Francis D. Coddenham Lodge, Cheltenham.
1883. ‡Longmaid, William Henry. 4 Rawlinson-road, Southport.
1875. *Longstaff, George Blundell, M.A., M.B., F.C.S., F.S.S. Southfield Grange, Wandsworth, S.W.
1871. §Longstaff, George Dixon, M.D., F.C.S. Butterknowle, Wandsworth, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Lord-street, Southport.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, London, S.W.
1887. *Love, A. E. H. St. John's College, Cambridge.
1886. *Love, E. F. J., M.A. Mason College, Birmingham.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 75 Oval road, Croydon.
1883. §Love, James Allen. 8 Eastbourne-road West, Southport.
1875. *Lovett, W. Jesse, F.I.C. Jessamine Cottage, Thornes, Wakefield.
1867. *Low, James F. Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwyn's Hill, East Grinstead, Sussex.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1863. *Lowe, Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.R.M.S. Shirenewton Hall, near Chepstow.
1884. ‡Lowe, F. J. Elm-court, Temple, London, E.C.
1868. ‡*Lowe, John, M.D. King's Lynn.*
1886. *Lowe, John Lander. 132 Bath-row, Birmingham.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.

Year of Election.

1881. ‡Lubbock, Arthur Rolfe. High Elms, Hayes, Kent.
1853. *LUBBOCK, Sir JOHN, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S., F.G.S. Down, Farnborough, Kent.
1881. ‡Lubbock, John B. High Elms, Hayes, Kent.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, London, W.
1878. ‡Lucas, Joseph. Tooting Graveney, London, S.W.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1875. ‡Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1867. *Luis, John Henry. Cidhmore, Dundee.
1873. ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1885. ‡LUMSDEN, ROBERT. Ferryhill House, Aberdeen.
1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 321 Newport-road, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Mining Engineering in Yorkshire College. 6 De Grey-road, Leeds.
1858. *Lupton, Arthur. Headingley, near Leeds.
1874. *LUPTON, SYDNEY, M.A. The Harehills, near Leeds.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡Lyell, Leonard, F.G.S. 92 Onslow-gardens, London, S.W.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1884. ‡Lyman, Roswell C. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. §Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1857. ‡Lyons, Robert D., M.B., M.R.I.A. 8 Merrion-square West, Dublin.
1878. ‡Lyte, Cecil Maxwell. Cotford, Oakhill-road, Putney, S.W.
1862. *LYTE, F. MAXWELL, F.C.S. 60 Finborough-road, London, S.W.

1852. ‡McAdam, Robert. 18 College-square East, Belfast.
1854. *MACADAM, STEVENSON, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. *MACADAM, WILLIAM IVISON. Surgeons' Hall, Edinburgh.
1868. ‡MACALISTER, ALEXANDER, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Strathmore House, Harvey-road, Cambridge.
1878. §MACALISTER, DONALD, M.A., M.D., B.Sc. St. John's College, Cambridge.
1879. §MacAndrew, James J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander, M.P., F.R.G.S. Raleigh Hall, Brixton Rise, London, S.W.
1884. ‡Macarthur, Alexander. Winnipeg, Canada.
1884. ‡Macarthur, D. Winnipeg, Canada.
1840. MACAULAY, JAMES, A.M., M.D. 25 Carlton-road, Maida Vale, London, N.W.
1840. *MacBrayne, Robert. Messrs. Black and Wingate, 5 Exchange-square, Glasgow.
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1855. ‡M'Cann, Rev. James, D.D., F.G.S. The Lawn, Lower Norwood, Surrey, S.E.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.

Year of
Election.

1887. *McCarthy, James. Bangkok, Siam.
1884. *McCarthy, J. J., M.D. Junior Army and Navy Club, London, S.W.
1884. ‡McCausland, Orr. Belfast.
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'Clintock, Admiral Sir Francis L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *M'Clure, J. H., F.R.G.S. Chavoire, Annecy, Haute Savoie, France.
1874. ‡M'Clure, Sir Thomas, Bart. Belmont, Belfast.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1883. ‡McCrossan, James. 92 Huskisson-street, Liverpool.
1876. ‡M'Culloch, Richard. 109 Douglas-street, Blythswood-square, Glasgow.
1884. ‡Macdonald, The Right Hon. Sir John Alexander, G.C.B., D.C.L., LL.D. Ottawa, Canada.
1886. §McDonald, John Allen. 6 Holly-place, Hampstead, London, N.W.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, W. C. 891 Sherbrooke-street, Montreal, Canada.
1878. ‡McDonnell, Alexander. St. John's, Island Bridge, Dublin.
1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1883. ‡MacDonnell, Rev. Canon J. C., D.D. Maplewell, Loughborough.
1878. ‡McDonnell, James. 32 Upper Fitzwilliam-street, Dublin.
1878. ‡McDonnell, Robert, M.D., F.R.S., M.R.I.A. 89 Merrion-square West, Dublin.
1884. ‡Macdougall, Alan. Toronto, Canada.
1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.
1871. ‡M'Farlane, Donald. The College Laboratory, Glasgow.
1885. ‡Macfarlane, J. M., D.Sc. 3 Bellevue-terrace, Edinburgh.
1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.
1884. ‡Macfie, K. N., B.A., B.C.L. Winnipeg, Canada.
1854. *Macfie, Robert Andrew. Dreghorn, Colinton, Edinburgh.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. ‡*M'George, Mungo. Nithsdale, Laurie Park, Sydenham, S.E.*
1884. ‡MacGillivray, James. 42 Catchurt-street, Montreal, Canada.
1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. 19 Place d'Armes, Montreal, Canada.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1885. ‡Macgregor, Alexander, M.D. 256 Union-street, Aberdeen.
1884. *MacGregor, James Gordon, M.A., D.Sc., F.R.S.E., Professor of Physics in Dalhousie College, Halifax, Nova Scotia, Canada.
1886. §McGregor, William. Kohima Lodge, Bedford.
1885. ‡M'Gregor-Robertson, J., M.A., M.B. 400 Great Western-road, Glasgow.
1876. ‡M'Grigor, Alexander B., LL.D. 19 Woodside-terrace, Glasgow.
1867. *M'Intosh, W. C., M.D., LL.D., F.R.S. L. & E., F.L.S., Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1884. ‡McIntyre, John, M.D. Odiham, Hants.
1883. ‡Mack, Isaac A. Trinity-road, Bootle.
1884. §Mackay, Alexander Howard, B.A., B.Sc. The Academy, Pictoū, Nova Scotia, Canada.
1885. §Mackay, John Yule, M.D. The University, Glasgow.

Year of Election.

1873. ‡McKENDRICK, JOHN G., M.D., F.R.S. L. & E., Professor of Physiology in the University of Glasgow. The University, Glasgow.
1883. ‡McKendrick, Mrs. The University, Glasgow.
1880. *Mackenzie, Colin. Junior Athenæum Club, Piccadilly, London, W.
1885. ‡*Mackenzie, J. T. Glenmuick, Ballater, N.B.*
1884. §McKenzie, Stephen, M.D. 26 Finsbury-circus, London, E.C.
1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1883. ‡Mackeson, Henry. Hythe, Kent.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 1 Westbourne-terrace, Hyde Park, London, W.
1867. ‡MACKIE, SAMUEL JOSEPH. 17 Howley-place, London, W.
1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.
1887. §Mackinder, H. J., F.R.G.S. Christ Church, Oxford.
1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
1865. ‡Mackintosh, Daniel, F.G.S. 32 Glover-street, Birkenhead.
1884. ‡Mackintosh, James B. Lehigh University, South Bethlehem, Pa., U.S.A.
1886. *Mackintosh, J. B. School of Mines, Fourth Avenue, New York, U.S.A.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLACHLAN, ROBERT, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.
1873. ‡McLandsborough, John, M.Inst.C.E., F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.
1885. *M'LAREN, The Right Hon. Lord, F.R.S.E. 46 Moray-place, Edinburgh.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1882. ‡Maclean, Inspector-General, C.B. 1 Rockstone-terrace, Southampton.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden Hill-road, London, W.
1868. §M'LEOD, HERBERT, F.R.S., F.C.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1875. ‡Macliver, D. 1 Broad-street, Bristol.
1875. ‡Macliver, P. S. 1 Broad-street, Bristol.
1861. *Maclure, John William, M.P., F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMahon, Colonel C. A. 20 Nevern-square, South Kensington, London, S.W.
1883. ‡MacMahon, Captain P. A., R.A., Instructor in Mathematics at the Royal Military Academy, Woolwich.
1878. *M'Master, George, M.A., J.P. Donnybrook, Ireland.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.
1884. *Macmillan, Angus, M.D. The Elms, Beverley-road, Hull.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1884. ‡*McMurrick, Playfair. Ontario Agricultural College, Guelph, Ontario, Canada.*
1871. ‡M'NAB, WILLIAM RAMSAY, M.D., Professor of Botany in the Royal College of Science, Dublin. St. Lawrence-road, Clontarf, Dublin.
1870. ‡*Macnaught, John, M.D. 74 Huskisson-street, Liverpool.*

Year of
Election.

1867. ‡M'Neill, John. Balhousie House, Perth.
1883. ‡McNicoll, Dr. E. D. 15 Manchester-road, Southport.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. §Maconochie, Archibald White. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
1886. §Macpherson, Lieut.-Colonel J. C., R.E. Ordnance Survey Office, Southampton.
1887. §McRae, Charles, M.A. Science and Art Department, South Kensington, London, S.W.
*Macrory, Edmund, M.A. 2 Ilchester-gardens, Prince's-square, London, W.
1876. **Mactear, James. 16 Burnbank-gardens, Glasgow.*
1883. ‡McWhirter, William. 170 Kent-road, Glasgow.
1887. §Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1883. ‡Maggs, Thomas Charles, F.G.S. Culver Lodge, Acton Vale, Middlesex, W.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Sir Philip, B.Sc. 48 Gloucester-place, Portman-square, London, W.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. Admiralty, Whitehall; London, S.W.
1887. §Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1885. *Maitland, Sir James R. G., Bart. Stirling, N.B.
1883. §Maitland, P. C. 136 Great Portland-street, London, W.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, U.S.A.
1887. §Manchester, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
1885. ‡Mann, George. 72 Bon Accord-street, Aberdeen.
Manning, His Eminence Cardinal. Archbishop's House, Westminster, S.W.
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel-Pleydell, J. C. Whatcombe, Blandford.
1887. *March, Henry Colley. 2 West-street, Rochdale.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1887. §Margetson, J. Charles. The Rocks, Limpley, Stoke.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. §Markham, Christopher. Sedgebrook, Northampton.
1864. ‡Markham, Clements R., C.B., F.R.S., F.L.S., Sec.R.G.S., F.S.A. 21 Eccleston-square, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
1881. *Marr, John Edward, M.A., F.G.S. St. John's College, Cambridge.
1857. ‡Marriott, William, F.C.S. 8 Belgrave-terrace, Huddersfield.
1887. §Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1887. §Marsden, Joseph. Ardenlea, Heaton, near Bolton.
1842. Marsden, Richard. Norfolk-street, Manchester.
1884. *Marsden, Samuel. St. Louis, Missouri, U.S.A.
1883. *Marsh, Henry. Cressy House, Woodsley-road, Leeds.
1887. §Marsh, J. E. Oxford.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.

Year of Election.

1882. *MARSHALL, A. MILNES, M.A., M.D., D.Sc., F.R.S., Professor of Zoology in Owens College, Manchester.
1881. ‡*Marshall, D. H. Greenhill Cottage, Rothesay.*
1881. *Marshall, John, F.R.A.S., F.G.S. Church Institute, Leeds.
1881. §Marshall, John Ingham Fearby. 28 St. Saviourgate, York.
1876. ‡Marshall, Peter. 6 Parkgrove-terrace, Glasgow.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1887. §Marshall, William. Thorncliffe, Dukinfield.
1886. *Marshall, William Bayley. 15 Augustus-road, Edgbaston, Birmingham.
1849. *MARSHALL, WILLIAM P., M.Inst.C.E. 15 Augustus-road, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1883. ‡Marten, Henry John. 4 Storey's-gate, London, S.W.
1887. *Martin, Rev. H. A. Laxton Vicarage, Newark.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1878. ‡MARTIN, H. NEWELL, M.A., M.D., D.Sc., F.R.S., Professor of Biology in Johns Hopkins University, Baltimore, U.S.A.
1883. *MARTIN, JOHN BIDDULPH, M.A., F.S.S. 17 Hyde Park-gate, London, S.W.
1884. §Martin, N. H., F.L.S. 29 Moseley-street, Newcastle-on-Tyne.
1836. Martin, Studley. Liverpool.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1886. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1886. ‡MARTINEAU, Sir THOMAS, J.P. West Hill, Augustus-road, Edgbaston, Birmingham.
1875. ‡*Martyn, Samuel, M.D.* 8 *Buckingham-villas, Clifton, Bristol.*
1883. ‡Marwick, James, LL.D. Killermont, Maryhill, Glasgow.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.A., M.P., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Salthrop, Wroughton, Wiltshire.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1868. ‡Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Messrs. Henry S. King & Co., 65 Cornhill, London, E.C.)
1876. §Mason, Robert. 6 Albion-crescent, Dowanhill, Glasgow.
1876. ‡Mason, Stephen. M.P. 9 Rosslyn-terrace, Hillhead, Glasgow.
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1885. ‡Masson, Orme, D.Sc. 58 Great King-street, Edinburgh.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.Inst.C.E. Salford Iron Works, Manchester.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 60 Harborne-road, Birmingham.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1885. ‡MATTHEWS, JAMES. Springhill, Aberdeen.
1885. ‡Matthews, J. Duncan. Springhill, Aberdeen.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Kenley, Surrey.

Year of Election.

1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1864. *Maxwell, Francis. 4 Moray-place, Edinburgh.
1887. §Maxwell, James. 29 Princess-street, Manchester.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S., F.R.G.S. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1868. ‡Mayall, J. E., F.C.S. Stork's Nest, Lancing, Sussex.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, London, W.C.
1835. Mayne, Edward Ellis. Rocklands, Stillorgan, Ireland.
1878. *Mayne, Thomas, M.P. 33 Castle-street, Dublin.
1863. ‡Mease, George D. Lydney, Gloucestershire.
1878. §Meath, The Most Rev. C. P. Reichel, D.D., Bishop of. Meath.
1884. ‡Mecham, Arthur. 11 Newton-terrace, Glasgow.
1883. ‡*Medd, John Charles, M.A. 99 Park-street, Grosvenor-square, London, W.*
1881. ‡Meek, Sir James. Middlethorpe, York.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, London, W.
1887. §Meisekke-Smith, W. 31 Plantage, Amsterdam.
1881. *MELDOLA, RAPHAEL, F.R.S., F.R.A.S., F.C.S., F.I.C., Professor of Chemistry in the City and Guilds of London Institute, Finsbury Technical Institute. 6 Brunswick-square, London, W.C.
1867. ‡MELDRUM, CHARLES, C.M.G., M.A., F.R.S., F.R.A.S. Port Louis, Mauritius.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. Mapperley Vicarage, Derby.
1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1881. §Melrose, James. Clifton, York.
1887. §Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, General Count, LL.D. 14 Rue de l'Elysée, Paris.
1862. ‡MENNELL, HENRY T. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1879. §Merivale, John Herman, M.A., Professor of Mining in the College of Science, Newcastle-on-Tyne.
1879. ‡Merivale, Walter. Indian Midland Railway, Sangor.
1877. ‡Merrifield, John, Ph.D., F.R.A.S. Gascoigne-place, Plymouth.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1872. *Messent, John. 429 Strand, London, W.C.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡MIALL, LOUIS C., F.G.S., Professor of Biology in Yorkshire College, Leeds.
1886. §Middlemore, Thomas. Holloway Head, Birmingham.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Middlesbrough.
1883. §Middleton, Henry. St. John's College, Cambridge.
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. Hudworth Cottage, Castle Eden, Co. Durham.
1876. *Middleton, Robert T. 197 West George-street, Glasgow.
1886. §Miles, Charles Albert. Buenos Ayres.
1881. §MILES, MORRIS. 44 Carlton-road, Southampton.

Year of Election.

1885. §Mill, Hugh Robert, D.Sc., F.R.S.E., F.C.S. 3 Glenorchy-terrace, Edinburgh.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1863. ‡Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1876. ‡Millar, William. Highfield House, Dennistoun, Glasgow.
1876. ‡Millar, W. J. 145 Hill-street, Garnethill, Glasgow.
1882. ‡Miller, A. J. 12 Cumberland-place, Southampton.
1876. ‡Miller, Daniel. 258 St. George's-road, Glasgow.
1875. ‡Miller, George. Brentry, near Bristol.
1884. ‡Miller, Mrs. Hugh. 51 Lauriston-place, Edinburgh.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. §Miller, Rev. John. The College, Weymouth.
1861. *Miller, Robert. Cranage Hall, Holmes Chapel, Cheshire.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1884. **Miller, Robert Kalley, M.A., Professor of Mathematics in the Royal Naval College, Greenwich, London, S.E.*
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1868. *Mills, Edmund J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in Anderson's College, Glasgow. 60 John-street, Glasgow.
1880. ‡Mills, Mansfeldt H. Tapton-grove, Chesterfield.
1834. Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. 13 New-street, Spring-gardens, London, S.W.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *Milne, John, F.R.S., F.G.S., Professor of Geology in the Imperial College of Engineering, Tokio, Japan. Ingleside, Birdhirst Rise, South Croydon, Surrey.
1885. ‡Milne, J. D. 14 Rubislaw-terrace, Aberdeen.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1867. *Milne-Home, David, M.A., LL.D., F.R.S.E., F.G.S. 10 York-place, Edinburgh.
1882. ‡Milnes, Alfred, M.A., F.S.S. 30 Almeric-road, London, S.W.
1880. §Minchin, G. M., M.A. Royal Indian Engineering College, Cooper's Hill, Surrey.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, London, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, London, W.
1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1885. ‡Mitchell, Rev. J. Mitford, B.A. 6 Queen's-terrace, Aberdeen.
1870. §Mitchell, John, J.P. York House, Clitheroe, Lancashire.
1868. ‡Mitchell, John, jun. Pole Park House, Dundee.
1885. §Mitchell, P. Chalmers. Christ Church, Oxford.
1862. **Mitchell, W. Stephen, M.A., LL.B.*
1879. ‡Mivart, St. George, M.D., F.R.S., F.L.S., F.Z.S., Professor of Biology in University College, Kensington. 71 Seymour-street, London, W.
1884. §Moat, Robert. Spring Grove, Bewdley.
1885. §Moffat, William. 7 Union-place, Aberdeen.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.

Year of Election.

1885. ‡Moir, James. 25 Carden-place, Aberdeen.
1861. ‡MOLESWORTH, Rev. Canon W. NASSAU, M.A., LL.D. Spotland, Rochdale.
1883. §Mollison, W. L., M.A. Clare College, Cambridge.
1878. ‡Molloy, Constantine, Q.C. 65 Lower Leeson-street, Dublin.
1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1887. *Mond, Ludwig. 20 Avenue-road, Regent's Park, London, N.W.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1882. *Montagu, Samuel, M.P. 12 Kensington Palace-gardens, London, W.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1884. §Moore, George Frederick. 25 Marlborough-road, Tue Brook, Liverpool.
1881. §Moore, Henry. Collingham, Maresfield-gardens, Fitzjohn's-avenue, London, N.W.
*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.
1877. ‡Moore, W. F. The Friary, Plymouth.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1877. ‡Moore, William Vanderkemp. 15 Princess-square, Plymouth.
1871. ‡MORE, ALEXANDER G., F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.
1881. ‡MORGAN, ALFRED. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, London, S.W.
1885. ‡Morgan, John. 57 Thomson-street, Aberdeen.
1887. §Morgan, John Gray. 38 Lloyd-street, Manchester.
1882. §Morgan, Thomas. Cross House, Southampton.
1878. ‡MORGAN, WILLIAM, Ph.D., F.C.S. Swansea.
1867. ‡Morison, William R. Dundee.
1883. §Morley, Henry Forster, M.A., D.Sc., F.C.S. University Hall, Gordon-square, London, W.C.
1881. ‡Morrell, W. W. York City and County Bank, York.
1880. ‡Morris, Alfred Arthur Vennor. Wernolau, Cross Inn R.S.O., Carmarthenshire.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. ‡Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡Morris, John. 40 Wellesley-road, Liverpool.
1880. ‡Morris, M. I. E. The Lodge, Penclawdd, near Swansea.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. ‡Morris, Rev. S. S. O., M.A., R.N., F.C.S. H.M.S. 'Garnet,' S. Coast of America.
1874. ‡Morrison, G. J., M.Inst.C.E. 5 Victoria-street, Westminster, S.W.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1886. ‡Morrison, John T. Scottish Marine Station, Granton, N.B.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 209 Edge-lane, Liverpool.

Year of
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1858. *MORTON, HENRY JOSEPH. 2 Westbourne-villas, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1887. §Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. 10 The Grove, Highgate, London, N.
1868. ‡MOSELEY, H. N., M.A., LL.D., F.R.S., Linacre Professor of Human and Comparative Anatomy in the University of Oxford. 14 St. Giles's, Oxford.
1883. ‡Moseley, Mrs. 14 St. Giles's, Oxford.
Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.
Moss, John. Otterspool, near Liverpool.
1878. *Moss, JOHN FRANCIS, F.R.G.S. Beechwood, Brincliffe, Sheffield.
1870. ‡Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1876. §Moss, RICHARD JACKSON, F.C.S., M.R.I.A. St. Aubin's, Ballybrack, Co. Dublin.
1873. **Mosse, George Staley.* 13 *Scarsdale-villas, Kensington, London, W.*
1864. *Mosse, J. R. Conservative Club, London, S.W.
1873. ‡Mossman, William. Ovenden, Halifax.
1869. §MOTT, ALBERT J., F.G.S. Detmore, Charlton Kings, Cheltenham.
1865. ‡Mott, Charles Grey. The Park, Birkenhead.
1866. §MOTT, FREDERICK T., F.R.G.S. Birstall Hill, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.
1878. *Moulton, J. Fletcher, M.A., F.R.S. 74 Onslow-gardens, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. ‡MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1882. ‡MOUNT-TEMPLE, The Right Hon. Lord. Broadlands, Romsey, Hants.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1887. §Moxon, Thomas B. County Bank, Manchester.
1886. *Moyles, Mrs. Thomas. The Beeches, Ladywood-road, Edgbaston, Birmingham.
1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1876. *Muir, John. 6 Park-gardens, Glasgow.
1874. ‡Muir, M. M. Pattison, M.A. F.R.S.E. Caius College, Cambridge.
1876. §Muir, Thomas, M.A., LL.D., F.R.S.E. Beechcroft, Bothwell, near Glasgow.
1884. *Muir, William Ker. Detroit, Michigan, U.S.A.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. Cowley-street, Westminster, S.W.
1871. *MUIRHEAD, HENRY, M.D., LL.D. Bushy Hill, Cambuslang, Lanarkshire.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. Meikle Cloak, Lochwinnoch, Renfrewshire.
1884. *Muirhead-Paterson, Miss Mary. Laurieville, Queen's Drive, Crosshill, Glasgow.
1883. §MULHALL, MICHAEL G. 19 Albion-street, Hyde-park, London, W.
1883. ‡Mulhall, Mrs. Marion. 19 Albion-street, Hyde-park, London, W.

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Election.

1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, London, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡MUNDELLA, The Right Hon. A. J., M.P., F.R.S., F.R.G.S. 16 Elvaston-place, London, S.W.
1876. ‡Munro, Donald, F.C.S. The University, Glasgow.
1885. §Munro, J. E. Crawford, LL.D., Professor of Political Economy in Owens College, Manchester.
1883. *Munro, Robert. Braehead House, Kilmarnock, N.B.
1872. *Munster, H. Sillwood Lodge, Brighton.
1864. ‡MURCH, JEROM. Cranwells, Bath.
1864. *Murchison, K. R. Brockhurst, East Grinstead.
1855. ‡Murdoch, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1884. §Murphy, Patrick. Newry, Ireland.
1887. §Murray, A. Hazeldean, Kersal, Manchester.
1869. ‡Murray, Adam. Westbourne Sussex-gardens, Hyde-park, London, W.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1859. ‡Murray, John, M.D. Forres, Scotland.
**Murray, John, M.Inst.C.E. Downlands, Sutton, Surrey.*
1884. §MURRAY, JOHN, F.R.S.E. *Challenger* Expedition Office, Edinburgh.
1884. ‡Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill University, Montreal, 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1883. ‡Murray, W. Vaughan. 4 Westbourne-crescent, Hyde Park, London, W.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1859. §MYLNE, ROBERT WILLIAM, F.R.S., F.G.S., F.S.A. 7 Whitehall-place, London, S.W.

1842. Nadin, Joseph. Manchester.
1886. §Nagel, D. H. Trinity College, Oxford.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1876. *Napier, Captain Johnstone. Laverstock House, Salisbury.
1872. ‡Nares, Captain Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. Maple-road, Surbiton.
1850. *NASMYTH, JAMES. Penshurst, Tunbridge.
1887. §Nason, Professor Henry B., Ph.D., F.C.S. Troy, New York, U.S.A.
1886. §Neale, E. Vansittart. 14 City-buildings, Corporation-street, Manchester.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.
1883. *Neild, Theodore. Dalton Hall, Manchester.
1887. §Neill, Joseph S. Claremont, Broughton Park, Manchester.
1887. §Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.
Neilson, Robert, J.P., D.L. Halewood, Liverpool.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1876. ‡Nelson, D. M. 11 Bothwell-street, Glasgow.
1886. ‡Nettlefold, Edward. 51 Carpenter-road, Edgbaston, Birmingham.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.

Year of
Election.

1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1857. ‡Neville, John, M.R.I.A. Roden-place, Dundalk, Ireland.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare Hill, Littleborough, Lancashire.
*Newall, Robert Stirling, F.R.S., F.R.A.S. Ferndene, Gateshead-upon-Tyne.
1886. §Newbolt, F. G. Edenhurst, Addlestone, Surrey.
1879. ‡Newbould, John. Sharrow Bank, Sheffield.
1866. *Newdigate, Albert L. Engineer's Office, The Harbour, Dover.
1883. ‡*Newman, Albert Robert. 33 Lisson-grove, Marylebone-road, London, N.W.*
1842. *Newman, Professor Francis William. 15 Arundel-crescent, Weston-super-Mare.
1860. *Newton, Alfred, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.
1883. ‡Newton, A. W. 7a Westcliffe-road, Birkdale, Southport.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1886. ‡Newton, William. 18 Fenchurch-street, London, E.C.
1883. ‡Nias, Miss Isabel. 56 Montagu-square, London, W.
1882. ‡Nias, J. B., B.A. 56 Montagu-square, London, W.
1867. ‡Nicholl, Thomas. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1866. ‡Nicholson, Sir Charles, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1838. *Nicholson, Cornelius, F.G.S., F.S.A. Ashleigh, Ventnor, Isle of Wight.
1871. §Nicholson, E. Chambers. Herne Hill, London, S.E.
1867. ‡Nicholson, Henry Alleyne, M.D., D.Sc., F.G.S., Professor of Natural History in the University of Aberdeen.
1887. *Nicholson, John Carr. Ashfield, Headingley, Leeds.
1884. §Nicholson, Joseph S., M.A., D.Sc., Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1887. §Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.
1881. ‡Nicholson, William R. Clifton, York.
1887. §Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1885. §Nicol, W. W. J., M.A., D.Sc., F.R.S.E. Mason Science College, Birmingham.
1878. ‡Niven, Charles, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. Aberdeen.
1886. §Niven George. Erkingholme, Coolhurst-road, London, N.
1877. ‡Niven, James, M.A. King's College, Aberdeen.
1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
1884. ‡Nixon, T. Alcock. 33 Harcourt-street, Dublin.
1863. *Noble, Captain Andrew, C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-on-Tyne.
1880. ‡Noble, John. Rossenstein, Thornhill-road, Croydon, Surrey.
1879. ‡Noble, T. S., F.G.S. Lendal, York.
1886. §Nock, J. B. 8 Vicarage-road, Edgbaston, Birmingham.
1887. §Nodal, John H. The Grange, Heaton Moor, near Stockport.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1882. §Norfolk, F. Elm Villa, Ordnance-road, Southampton.
1859. ‡*Norfolk, Richard. Ladygate, Beverley.*

Year of Election.

1868. ‡Norgate, William. Newmarket-road, Norwich.
1863. ‡NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., F.L.S. Burnmoor Rectory, Fence House, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Coalbrookdale, Shropshire.
1881. §North, Samuel William, M.R.C.S., F.G.S. 84 Micklegate, York.
1881. ‡North, William, B.A., F.C.S. 28 Regent's Park-road, London, N.W.
*NORTHWICK, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1878. ‡*Nugent, Edward. Seel's-buildings, Liverpool.*
1883. ‡Nunnerley, John. 46 Alexandra-road, Southport.
1887. §Nursey, Perry Fairfax. 161 Fleet-street, London, E.C.
1883. §Nutt, Miss Lilian. Rosendale Hall, West Dulwich, London, S.E.

1882. §Obach, Eugene, Ph.D. 2 Victoria-road, Old Charlton, Kent.
1878. ‡*O'Brien, Murrough. 1 Willow-terrace, Blackrock, Co. Dublin.*
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡*O'Carroll, Joseph F. 78 Rathgar-road, Dublin.*
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, London, E.C.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1884. ‡Odlum, Edward, M.A. Pembroke, Ontario, Canada.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1877. §Ogden, Joseph. 21 Station-road, South Norwood, London, S.E.
1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡Ogilvie, F. Grant, M.A., B.Sc. Gordon's College, Aberdeen.
1874. ‡*Ogilvie, Thomas Robertson. Bank Top, 3 Lyle-street, Greenock, N.B.*
1859. ‡Ogilvy, Rev. C. W. Norman. Baldovan House, Dundee.
1863. ‡OGILVY, Sir JOHN, Bart. Inverquharity, N.B.
*Ogle, William, M.D., M.A. The Elms, Derby.
1837. ‡O'Hagan, John, M.A., Q.C. 22 Upper Fitzwilliam-street, Dublin.
1884. §O'Halloran, J. S., F.R.G.S. Royal Colonial Institute, Northumberland-avenue, London, W.C.
1887. §Oldham, Charles. Syrian House, Sale, near Manchester.
1881. ‡Oldfield, Joseph. Lendal, York.
1853. ‡OLDHAM, JAMES, M.Inst.C.E. Cottingham, near Hull.
1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.
1863. ‡Oliver, Daniel, F.R.S., F.L.S., Professor of Botany in University College, London. Royal Gardens, Kew, Surrey.
1887. §Oliver, F. W. Royal Gardens, Kew, Surrey.
1883. ‡Oliver, J. A. Westwood. Braehead House, Lochwinnoch, Scotland.

Year of Election.

1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1882. §Olsen, O. T., F.R.A S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
*OMMANNEY, Admiral Sir ERASMUS, C.B., F.R.S., F.R.A.S., F.R.G.S. The Towers, Yarmouth, Isle of Wight.
1880. *Ommanney, Rev. E. A. 123 Vassal-road, Brixton, London, S.W.
1887. §O'Neill, Charles. 72 Denmark-road, Manchester.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1883. ‡Oppert, Gustav, Professor of Sanskrit. Madras.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1883. §Ord, Miss Maria. Fern Lea, Park-crescent, Southport.
1883. §Ord, Miss Sarah. Fern Lea, Park-crescent, Southport.
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1842. ORMEROD, GEORGE WAREING, M.A., F.G.S. Woodway, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham Hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1835. ORPEN, JOHN H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1883. ‡Orpen, Miss. 58 Stephen's-green, Dublin.
1884. *Orpen, Captain R. T., R.E. 58 Stephen's-green, Dublin.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1873. ‡Osborn, George. 47 Kingscross-street, Halifax.
1887. §O'Shea, L. J., B.Sc. Firth College, Sheffield.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1869. *Osler, Sidney F. Chesham Lodge, Lower Norwood, Surrey, S.E.
1884. ‡Osler, William, M.D., Professor of the Institutes of Medicine in McGill University, Montreal, Canada.
1884. ‡O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. New Place House, Southampton.
1881. *Ottewell, Alfred D. 83 Siddals-road, Derby.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1870. ‡Owen, Harold. Tue Brook Villa, Liverpool.
OWEN, Sir RICHARD, K.C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E. Sheen Lodge, Mortlake, Surrey, S.W.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *PALGRAVE, R. H. INGLIS, F.R.S., F.S.S. Belton, Great Yarmouth.
1883. ‡Palgrave, Mrs. R. H. Inglis. Belton, Great Yarmouth.
1873. ‡Palmer, George, M.P. The Acacias, Reading, Berks.
1878. *Palmer, Joseph Edward. Lyons Mills, Straffan Station, Dublin.
1887. *Palmer, Miss Mary Kate. Kilburn House, Sherwood, Notts.
1866. ‡Palmer, William. Kilbourne House, Cavendish Hill, Sherwood, Notts.
1872. *Palmer, W. R. 1 The Cloisters, Temple, E.C.

Year of Election.

Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1883. §Pant, F. J. van der. Clifton Lodge, Kingston-on-Thames.
1886. ‡Panton, George A., F.R.S.E. 47 Wheeley's-road, Edgbaston, Birmingham.
1884. §Panton, Professor J. Hoyes, M.D. Ontario Agricultural College, Guelph, Ontario, Canada.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. Barrow-in-Furness, Lancashire.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
1874. ‡Parker, Henry R., LL.D. Methodist College, Belfast.
Parker, Richard. Dunscombe, Cork.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling, F.L.S. 6 St. Mary's-row, Birmingham.
1864. ‡PARKES, WILLIAM. 23 Abingdon-street, Westminster, S.W.
1879. §Parkin, William, F.S.S. The Mount, Sheffield.
1887. §Parkinson, James. Station-road, Turton, Bolton.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire.
1841. Parnell, Edward A., F.C.S. Ashley Villa, Swansea.
1862. *Parnell, John, M.A. 1 The Common, Upper Clapton, London, E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1877. ‡Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. 10 Connaught-place, London, W.
1878. ‡Parsons, Hon. and Rev. R. C. 10 Connaught-place, London, W.
1883. ‡*Part, C. T. 5 King's Bench-walk, Temple, London, E.C.*
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881. §Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1884. *Paton, David. Johnstone, Scotland.
1883. *Paton, Henry, M.A. 15 Myrtle-terrace, Edinburgh.
1884. *Paton, Hugh. 992 Sherbrooke-street, Montreal, Canada.
1883. ‡Paton, Rev. William. The Ferns, Parkside, Nottingham.
1887. §Paterson, A. M., M.D. The Owens College, Manchester.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. Henry. 3 New-square, Lincoln's Inn, London, W.C.
1884. ‡Patterson, Edward Mortimer. Fredericton, New Brunswick, Canada.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1876. §Patterson, T. L. Belmont, Margaret-street, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡Pattinson, John, F.C.S. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. §Pattison, Samuel Rowles, F.G.S. 11 Queen Victoria-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1883. ‡Paul, G., F.G.S. Filey, Yorkshire.

Year of Election.

1863. ‡Pavy, Frederick William, M.D., F.R.S. 35 Grosvenor-street, London, W.
1887. §Paxman, James. Hill House, Colchester.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-on-Tyne.
1877. *Payne, J. C. Charles. Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Dr. Joseph F. 78 Wimpole-street, London, W.
1886. ‡Payton, Henry. Eversleigh, Somerset-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡Peach, B. N., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1883. ‡Peacock, Ebenezer. 8 Mandeville-place, Manchester-square, London, W.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1881. *Pearce, Horace, F.R.A.S., F.L.S., F.G.S. The Limes, Stourbridge.
1886. *Pearce, Mrs. Horace. The Limes, Stourbridge.
1882. §Pearce, Walter, M.B., B.Sc., F.C.S. St. Mary's Hospital, Paddington, London, W.; and Craufurd, Ray Mead, Maidenhead.
1876. ‡Pearce, Sir William, Bart., M.P. Elmpark House, Govan, Glasgow.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 3 Cursitor-street, London, E.C.
1887. §Pearse, J. Walter. Brussels.
1881. ‡Pearse, Richard Seward. Southampton.
1883. ‡Pearson, Arthur A. Colonial Office, London, S.W.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Grove Farm, Merlin, Raleigh, Ontario, Canada.
1881. ‡Pearson, Richard. 23 Bootham, York.
1870. ‡Pearson, Rev. Samuel. 48 Prince's-road, Liverpool.
1883. *Pearson, Thomas H. Golborne Park, near Newton-le-Willows, Lancashire.
1863. §Pease, H. F. Brinkburn, Darlington.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1883. ‡Peck, John Henry. 52 Hoghton-street, Southport.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
*Peckover, Algernon, F.L.S. Sibald's Holme, Wisbech, Cambridgeshire.
1885. ‡Peddie, W. Spring Valley Villa, Morningside-road, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡Peek, C. E. Conservative Club, London, S.W.
1878. *Peek, William. 16 Belgrave-place, Brighton.
1873. ‡Peel, Thomas. 9 Hampton-place, Bradford, Yorkshire.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, London, S.W.
1884. ‡Pegler, Alfred. Elmfield, Southampton.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.

Year of Election.

1861. *Pender, Sir John, K.C.M.G., M.P. 18 Arlington-street, London, S.W.
1887. §Pendlebury, William H. Christ Church, Oxford.
1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1881. ‡Penty, W. G. Melbourne-street, York.
1875. ‡Perceval, Rev. Canon John, M.A., LL.D. Rugby.
1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S. 1 Gloucester-crescent, Hyde Park, London, W.
*Perigal, Frederick. Thatched House Club, St. James's-street, London, S.W.
1886. §Perkin, T. Dix. Greenford Green, Harrow, Middlesex.
1868. *PERKIN, WILLIAM HENRY, Ph.D., F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow, Middlesex.
1884. ‡Perkin, William Henry, jun., Ph.D. The Chestnuts, Sudbury, Harrow, Middlesex.
1877. ‡Perkins, Loftus. Seaford-street, Regent-square, London, W.C.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1885. §Perrin, Miss Emily. Girton College, Cambridge.
1886. §Perrin, Henry S. 31 St. John's Wood Park, London, N.W.
1886. ‡Perrin, Mrs. 23 Holland Villas-road, Kensington, London, W.
Perry, The Right Rev. Charles, M.A., D.D. 32 Avenue-road, Regent's Park, London, N.W.
1879. ‡Perry, James. Roscommon.
1874. *PERRY, JOHN, LL.D., F.R.S., Professor of Engineering and Applied Mathematics in the Technical College, Finsbury. 10 Penywern-road, South Kensington, London, S.W.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1870. *PERRY, Rev. S. J., LL.D., F.R.S., F.R.A.S., F.R.M.S. Stonyhurst College Observatory, Whalley, Blackburn.
1886. ‡Perry, William. Hanbury Villa, Stourbridge.
1883. §Petrie, Miss Anne S. Stone Hill, Rochdale.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 5 Fourth-avenue, Brighton.
1882. ‡Pfoundes, Charles, F.R.G.S. Spring Gardens, London, S.W.
1886. §Phelps, Colonel A. 23 Augustus-road, Edgbaston, Birmingham.
1884. ‡Phelps, Charles Edgar. Carisbrooke House, The Park, Nottingham.
1884. ‡Phelps, Mrs. Carisbrooke House, The Park, Nottingham.
1886. ‡Phelps, Hon. E. J. American Legation, Members' Mansions, Victoria-street, London, S.W.
1886. ‡Phelps, Mrs. Hamshall, Birmingham.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
Philips, Robert N., M.P. The Park, Manchester.
1877. §Philips, T. Wishart. 53 Tredegar-square, Bow, London, E.
1863. ‡Philipson, Dr. 1 Savile-row, Newcastle-on-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1887. §Phillips, H. Harcourt, F.C.S. 18 Exchange-street, Manchester.
1880. §Phillips, John H., Hon. Sec. Philosophical and Archæological Society, Scarborough.
1883. ‡Phillips, Mrs. Leah R. 1 East Park-terrace, Southampton.
1883. ‡Phillips, S. Rees. Wanford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1868. ‡PHIPSON, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.

Year of Election.

1884. *Pickard, Rev. H. Adair, M.A. 5 Canterbury-road, Oxford.
1883. *Pickard, Joseph William. Lindow-square, Lancaster.
1885. *PICKERING, SPENCER U. 48 Bryanston-square, London, W.
1864. ‡Pickering, William. Oak View, Clevedon.
1884. *Pickett, Thomas E., M.D. Maysville, Mason County, Kentucky, U.S.A.
1870. ‡Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 4 The Grove, Highgate, London, N.
1865. ‡PIKE, L. OWEN. 201 Maida-vale, London, W.
1873. ‡Pike, W. H. University College, Toronto, Canada.
1857. ‡Pilkington, Henry M., LL.D., Q.C. 45 Upper Mount-street, Dublin.
1883. §Pilling, R. C. The Robin's Nest, Blackburn.
Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1884. ‡*Pinart, A. G. N. L. 74 Market-street, San Francisco, U.S.A.*
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡PIRIE, Rev. G., M.A., Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1884. ‡Pirz, Anthony. Long Island, New York, U.S.A.
1887. §Pitkin, James. 56 Red Lion-street, Clerkenwell, London, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡Pitt, George Newton, M.A., M.D. 34 Ashburn-place, South Kensington, London, S.W.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1883. §Pitt, Sydney. 34 Ashburn-place, South Kensington, London, S.W.
1868. ‡PITT-RIVERS, Lieut.-General A. H. L., F.R.S., F.G.S., F.S.A. 4 Grosvenor-gardens, London, S.W.
1872. ‡Plant, Mrs. H. W. 28 Evington-street, Leicester.
1869. §PLANT, JAMES, F.G.S. 40 West-terrace, West-street, Leicester.
1886. §Player, J. H. 5 Prince of Wales-terrace, Kensington, London, W.
1842. PLAYFAIR, The Right Hon. Sir LYON, K.C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡PLAYFAIR, Lieut.-Colonel Sir R. L., K.C.M.G., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 31 George-street, Hanover-square, London, W.
1883. *Plimpton, R. T., M.D. 23 Lansdowne-road, Clapham-road, London, S.W.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, F.C.S. Bodnant Hall, near Conway.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1846. ‡POLE, WILLIAM, Mus.Doc., F.R.S., M.Inst.C.E. Athenæum Club, Pall Mall, London, S.W.
1887. *Poles, A. J. S. Moor End, Kersal, Manchester.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1868. ‡PORTAL, WYNDHAM S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D. Brechin Lodge, Cambridge-road, Southport.
1874. ‡Porter, Rev. J. Leslie, D.D., LL.D., President of Queen's College, Belfast.

Year of Election.

1886. §Porter, Paxton. Birmingham and Midland Institute, Birmingham.
1866. §Porter, Robert. Highfield, Long Eaton, Nottingham.
1883. ‡Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
1887. §Potter, Edmund P. Hollinhurst, Bolton.
1883. ‡Potter, M. C., B.A. St. Peter's College, Cambridge.
Potter, Richard, M.A. 10 Brookside, Cambridge.
1883. §Potts, John. 33 Chester-road, Macclesfield.
1886. *Poulton, Edward B., M.A. Wykeham House, Oxford.
1873. *Powell, Francis S., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. §Powell, John. Wannarlwydd House, near Swansea.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, Mosley-street, Manchester.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuk, Uddingston, Scotland.
1883. ‡Poynting, J. H., M.A., Professor of Physics in the Mason College, Birmingham. 385 Hagley-road, Edgbaston, Birmingham.
1884. §Prance, Courtenay C. Hatherley Court, Cheltenham.
1884. *Prankerd, A. A., D.C.L. Brazenose College, Oxford.
1869. *Preece, William Henry, F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.
1884. *Premio-Real, His Excellency the Count of. Quebec, Canada.
*Prestwich, Joseph, M.A., F.R.S., F.G.S., F.C.S. Shoreham, near Sevenoaks.
1884. *Prevost, Major L. de T. 2nd Battalion Argyll and Sutherland Highlanders.
1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-fields, London, W.C.
1856. *Price, Rev. Bartholomew, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford, 11 St. Giles's, Oxford.
1872. ‡Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
1882. ‡Price, John E., F.S.A. 27 Bedford-place, Russell-square, London, W.C.
Price, J. T. Neath Abbey, Glamorganshire.
1881. §Price, Peter. Crockherbtown, Cardiff.
1875. *Price, Rees. 1 Montague-place, Glasgow.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1876. ‡Priestley, John. 174 Lloyd-street, Greenheys, Manchester.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1883. §Prince, Thomas. Horsham-road, Dorking.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1846. *Pritchard, Rev. Charles, D.D., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1876. *Pritchard, Urban, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1881. §Procter, John William. Ashcroft, Nunthorpe, York.
1863. ‡Proctor, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.

Year of Election.

1885. ‡Profeit, Dr. Balmoral, N.B.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1884. *Proudfoot, Alexander. 2 Phillips-place, Montreal, Canada.
1879. *Prouse, Oswald Milton, F.G.S., F.R.G.S. 4 Cambridge-villas, Richmond Park-road, Kingston-on-Thames.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Tayside, Perth.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
1887. §PUMPHREY, WILLIAM. Lyncombe, Bath.
Punnet, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1885. §Purdie, Thomas, B.Sc., Ph.D., Professor of Chemistry in the University of St. Andrews. St. Andrews, N.B.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1882. ‡Purrott, Charles. West End, near Southampton.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stafford-place, Oxford-street, London, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1883. §Pye-Smith, Arnold. 16 Fairfield-road, Croydon.
1883. §Pye-Smith, Mrs. 16 Fairfield-road, Croydon.
1868. §PYE-SMITH, P. H., M.D., F.R.S. 54 Harley-street, W.; and Guy's Hospital, London, S.E.
1879. §Pye-Smith, R. J. 350 Glossop-road, Sheffield.
1861. *Pyne, Joseph John. The Willows, Albert-road, Southport.

1870. ‡Rabbits, W. T. Forest Hill, London, S.E.
1887. §Rabone, John. Penderell House, Hamstead-road, Birmingham.
1860. ‡RADCLIFFE, CHARLES BLAND, M.D. 25 Cavendish-square, London, W.
1870. ‡Radcliffe, Sir D. R. Phœnix Safe Works, Windsor, Liverpool.
1887. §Radcliffe, James. 108 Higher King-street, Dukinfield, Cheshire.
1877. ‡Radford, George D. Mannamead, Plymouth.
1879. ‡Radford, R. Heber. Wood Bank, Pitsmoor, Sheffield.
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, The Right Hon. Lord. 70 Portland-place, London, W.
1878. ‡RAE, JOHN, M.D., LL.D., F.R.S., F.R.G.S. 4 Addison-gardens, Kensington, London, W.
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1887. *Ragdale, John Rowland. Derby-place, Whitefield, Manchester.
1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡RAMSAY, ALEXANDER, F.G.S. 2 Cowper-road, Acton, Middlesex, W.
1845. ‡RAMSAY, Sir ANDREW CROMBIE, LL.D., F.R.S., F.G.S. 15 Cromwell-crescent, South Kensington, London, S.W.
1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.

Year of Election.

1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. ‡Ramsay, John. Kildalton, Argyleshire.
1884. ‡RAMSAY, R. A. 1134 Sherbrooke-street, Montreal, Canada.
1867. *Ramsay, W. F., M.D. Inveresk House, Nevern-road, London, S.W.
1876. *RAMSAY, WILLIAM, Ph.D., Professor of Chemistry in University College, London, W.C.
1883. ‡Ramsay, Mrs. 12 Arundel-gardens, London, W.
1885. ‡Ramsay, Major. Straloch, N.B.
1887. §Ramsbottom, John. Fernhill, Alderley Edge, Cheshire.
1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford Yorkshire.
1835. *Rance, Henry. St. Andrew's-street, Cambridge.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, London, S.W.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
1868. *Ransom, Edwin, F.R.G.S. Ashburnham-road, Bedford.
1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A., M.D., F.R.S. Devisdale, Bowdon, Manchester.
Ransome, Thomas. Hest Bank, near Lancaster.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's Inn, London, W.C.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1864. ‡Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. Beechwood House, Liverpool.
1874. ‡RAVENSTEIN, E. G., F.R.G.S. 29 Lambert-road, Brixton, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.
1855. *RAWLINSON, Major-General Sir HENRY C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1887. §Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1875. §RAWSON, Sir RAWSON W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1886. §Rawson, W. Stepney, M.A., F.C.S. 68 Cornwall-gardens, Queen's gate, London, S.W.
1883. ‡Ray, Miss Catherine. Mount Cottage, Flask-walk, Hampstead, London, N.W.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S., F.R.G.S. Terling Place, Witham, Essex.
1883. *Rayne, Charles A., M.B., B.Sc., M.R.C.S. 3 Queen-street, Lancaster.
1865. ‡Read, William. Albion House, Epworth, Rawtry.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., F.R.S.E. 9 Moray-place, Edinburgh.
1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. 5 Crowhurst-road, Brixton, London, S.W.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1887. §Redhead, R. Milne. Springfield, Seedley, Manchester.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.

Year of Election.

Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡REED, Sir EDWARD J., K.C.B., M.P., F.R.S. 74 Gloucester-road, South Kensington, London, W.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1881. §Reid, Arthur S., B.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.G.S. 28 Jermyn-street, London, S.W.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1884. ‡Reid, Rev. James, B.A. Bay City, Michigan, U.S.A.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1881. ‡Reid, William. 19½ Blake-street, York.
1875. §REINOLD, A. W., M.A., F.R.S., Professor of Physical Science in the Royal Naval College, Greenwich, S.E.
1863. §RENALS, E. 'Nottingham Express' Office, Nottingham.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1884. ‡*Retallack, Captain Francis. 6 Beauchamp-avenue, Leamington.*
1883. *Reynolds, A. H. Manchester and Salford Bank, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.A., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in Owens College, Manchester. Fallowfield, Manchester.
1858. §REYNOLDS, RICHARD, F.C.S. 13 Briggate, Leeds.
1887. §Rhodes, George W. The Cottage, Victoria Park, Manchester.
1883. ‡Rhodes, Dr. James. 25 Victoria-street, Glossop.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1863. ‡RICHARDSON, BENJAMIN WARD, M.A., M.D., LL.D., F.R.S. 25 Manchester-square, London, W.
1861. ‡Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. 4 Northumberland-avenue, Putney, S.W.
1863. *Richardson, Edward. Warkworth, Northumberland.
1887. *Richardson, Miss Emma. Conway House, Dunmurry, Co. Antrim.
1882. §Richardson, Rev. George, M.A. The College, Winchester.
1884. *Richardson, George Straker. Kingsley House, Holland-road, Brighton.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1881. ‡Richardson, W. B. Elm Bank, York.
1861. ‡Richardson, William. 4 Edward-street, Werneth, Oldham.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1886. §Richmond, Robert. Leighton Buzzard.
1863. ‡Richter, Otto, Ph.D. 407 St. Vincent-street, Glasgow.
1868. ‡RICKETTS, CHARLES, M.D., F.G.S. 18 Hamilton-square, Birkenhead.
1877. ‡Ricketts, James, M.D. St. Helen's, Lancashire.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1861. *Riddell, Henry B. Whitefield House, Rothbury, Morpeth.
1883. *Rideal, Samuel. Mayow-road, Forest Hill, Kent, S.E.
1872. ‡*Ridge, James. 98 Queen's-road, Brighton.*
1862. ‡Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1884. ‡Ridout, Thomas. Ottawa, Canada.

Year of Election.
1863. *Rigby, Samuel. Fern Bank, Liverpool-road, Chester.
1881. *Rigg, Arthur. 71 Warrington-crescent, London, W.
1883. *Rigg, Edward, M.A. Royal Mint, London, E.
1883. ‡Rigg, F. F., M.A. 32 Queen's-road, Southport.
1883. *Rigge, Samuel Taylor. Balmoral-place, Halifax.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*Ripon, The Most Hon. the Marquis of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 1 Carlton-gardens, London, S.W.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡*Ritchie, Robert. 14 Hill-street, Edinburgh.*
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John. Babbicombe, near Torquay.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *Robbins, John, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1878. ‡Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.
1887. *Roberts, Evan. 3 Laurel-bank, Alexandra-road, Manchester.
1859. ‡Roberts, George Christopher. Hull.
1870. *Roberts, Isaac, F.G.S. Kennessee, Maghull, Lancashire.
1883. ‡Roberts, Ralph A. 23 Clyde-road, Dublin.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. Clare College, Cambridge.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1883. ‡Roberts, Sir William, M.D., F.R.S. 89 Mosley-street, Manchester.
1868. *Roberts-Austen, W. Chandler, F.R.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal School of Mines. Royal Mint, London, E.
1883. ‡Robertson, Alexander. Montreal, Canada.
1884. *Robertson, Andrew. Elmbank, Dorchester-street, Montreal, Canada.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.
1871. ‡Robertson, George, M.Inst.C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1883. ‡Robertson, George H. The Nook, Gateacre, near Liverpool.
1883. ‡Robertson, Mrs. George H. The Nook, Gateacre, near Liverpool.
1870. *Robertson, John. 4 Albert-road, Southport.
1876. ‡Robertson, R. A. Newthorn, Ayton-road, Pollokshields, Glasgow.
1866. ‡Robertson, Sir William Tindal, M.D., M.P. 9 Belgrave-terrace, Brighton.
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1886. §Robinson, Edward E. 56 Dovey-street, Liverpool.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Beech Hill, Armagh.
1887. §Robinson, Henry. 7 Westminster-chambers, London, S.W.
1873. ‡Robinson, Hugh. 82 Donegall-street, Belfast.
1887. §Robinson, James. Akroydon Villa, Halifax, Yorkshire.
1861. ‡Robinson, John, M.Inst.C.E. Atlas Works, Manchester.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1887. §Robinson, Richard. Bellfield Mill, Rochdale.
1881. §Robinson, Richard Atkinson. 195 Brompton-road, London, S.W.
1875. *Robinson, Robert, M.Inst.C.E., F.G.S. 2 West-terrace, Darlington.
1860. ‡Robinson, Admiral Sir Robert Spencer, K.C.B., F.R.S. 61 Eaton-place, London, S.W.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.

Year of
Election.

1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. ‡Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street Westminster, S.W.
1876. ‡Robson, Hazleton R. 14 Royal-crescent West, Glasgow.
1855. ‡*Robson, Neil. 127 St. Vincent-street, Glasgow.*
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.
1885. §Rodger, Edward. 1 Claremont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. 12 John-street, Adelphi, London, W.C.
1872. ‡Rodwell, George F., F.R.A.S., F.C.S. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1860. ‡Rogers, James E. Thorold, Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Saltren, M.A. Gwennap, Redruth, Cornwall.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.
1883. ‡Rogers, Thomas Stanley, LL.B. 77 Albert-road, Southport.
1884. *Rogers, Walter M. Lamowa, Falmouth.
1886. ‡Rogers, W. Woodbourne. Wheeley's-road, Edgbaston, Birmingham.
1876. §Rollit, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1876. ‡Romanes, George John, M.A., LL.D., F.R.S., F.L.S. 18 Cornwall-terrace, Regent's Park, London, N.W.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. ‡Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1881. *Roper, W. O. Eadenbreck, Lancaster.
1855. *Roscoe, Sir Henry Enfield, B.A., Ph.D., LL.D., D.C.L., M.P., F.R.S., F.C.S. (President). 10 Bramham-gardens, London, S.W.; and Victoria Park, Manchester.
1883. *Rose, J. Holland, M.A. Aboyne, Bedford Hill-road, Balham, London, S.W.
1885. ‡Ross, Alexander. Riverfield, Inverness.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡Ross, David, LL.D. 32 Nelson-street, Dublin.
1887. §Ross, Edward. Marple, Cheshire.
1880. ‡Ross, Captain G. E. A., F.R.G.S. 8 Collingham-gardens, Cromwell-road, London, S.W.
1872. ‡Ross, James, M.D. Tenterfield House, Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1874. ‡*Ross, Rev. William. Chapelhill Manse, Rothesay, Scotland.*
1880. §Ross, Major William Alexander. Acton House, Acton, London, W.
1869. *Rosse, The Right Hon. the Earl of, B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1884. *Rouse, M. L. 343 Church-street, Toronto, Canada.
1861. ‡Routh, Edward J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1881. ‡Routh, Rev. William, M.A. Clifton Green, York.
1872. **Row, A. V. Nursing Observatory, Daba-gardens, Vizagapatam, India. (Care of Messrs. King & Co., 45 Pall Mall, London, S.W.)*

Year of Election.

1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1887. §Rowe, Rev. Alfred W. Felstead, Essex.
1881. ‡Rowe, Rev. G. Lord Mayor's Walk, York.
1865. §Rowe, Rev. John. Load Vicarage, Langport, Somerset.
1877. ‡ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1855. *ROWNEY, THOMAS H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway. Salerno, Salthill, Galway.
1881. *Rowntree, Joseph. 37 St. Mary's, York.
1881. *ROWNTREE, J. S. The Mount, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1883. ‡Roy, Charles S., M.D., F.R.S , Professor of Pathology in the University of Cambridge. Trinity College, Cambridge.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
1875. ‡RÜCKER, A. W., M.A., F.R.S., Professor of Physics in the Royal School of Mines. Errington, Clapham Park, London, S.W.
1869. §RUDLER, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Queen Anne's-gate, London, S.W.
1884. §Runtz, John. Linton Lodge, Lordship-road, Stoke Newington, London, N.
1887. §Ruscoe, John, F.G.S, Ferndale, Gee Cross, near Manchester.
1847. ‡RUSKIN, JOHN, M.A., F.G.S. Brantwood, Coniston, Ambleside.
1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1884. §Russell, George. Hoe Park House, Plymouth.
1883. *Russell, J. W. Merton College, Oxford.
Russell, John. 39 Mountjoy-square, Dublin.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, London, W.
1876. §Russell, R., F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.
1862. §RUSSELL, W. H. L., B.A., F.R.S. 3 Ridgmount-terrace, Highgate, London, N.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., F.C.S., Lecturer on Chemistry in St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1886. §Rust, Arthur. Eversleigh, Leicester.
1883. *Ruston, Joseph, M.P. Monk's Manor, Lincoln.
1871. §RUTHERFORD, WILLIAM, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
1887. §Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.
1881. ‡Rutson, Albert. Newby Wiske, Thirsk.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1879. ‡Ruxton, Rear-Admiral Fitzherbert, R.N., F.R.G.S. 41 Cromwell-gardens, London, S.W.
1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1886. ‡Ryland, F. Augustus-road, Edgbaston, Birmingham.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. *Sabine, Robert. 3 Great Winchester-street-buildings, London, E.C.
1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.

Year of
Election.

1871. ‡Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1885. ‡Saint, W. Johnston. 11 Queen's-road, Aberdeen.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1886. §St. Clair, George, F.G.S. 127 Bristol-road, Birmingham.
1887. *SALFORD, the Right Rev. the Bishop of. Bishop's House, Salford.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., LL.D., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1883. ‡Salmond, Robert G. The Nook, Kingswood-road, Upper Norwood, S.E.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1883. ‡Salt, Shirley H., M.A. 73 Queensborough-terrace, London, W.
1872. ‡SALVIN, OSBERT, M.A., F.R.S., F.L.S. Hawksfold, Haslemere.
1887. §Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1861. *Sandeman, Archibald, M.A. Garry Cottage, Perth.
1876. ‡Sandeman, David. Woodlands, Lenzie, Glasgow.
1883. ‡Sandeman, E. 53 Newton-street, Greenock.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. *Sanders, Charles J. B. Pennsylvania, Exeter.
1884. ‡Sanders, Henry. 185 James-street, Montreal, Canada.
1872. ‡Sanders, Mrs. 8 Powis-square, Brighton.
1883. ‡Sanderson, Surgeon Alfred. East India United Service Club, St. James's-square, London, S.W.
1872. ‡SANDERSON, J. S. BURDON, M.D., LL.D., F.R.S., Professor of Physiology in the University of Oxford. 50 Banbury-road, Oxford.
1883. ‡Sanderson, Mrs. Burdon. 50 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1886. §Sankey, Percy E. Lyndhurst, St. Peter's, Kent.
1886. §Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1881. ‡SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, London, W.
1883. ‡Saunders, Rev. J. C. Cambridge.
1846. ‡SAUNDERS, TRELAWNEY W., F.R.G.S. 3 Elmfield, on the Knowles, Newton Abbot, Devon.
1864. ‡*Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.*
1884. ‡Saunders, William. London, Ontario, Canada.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.
1887. §Savage, Rev. E. B., M.A. St. Thomas' Parsonage, Douglas, Isle of Man.
1871. §Savage, W. D. Ellerslie House, Brighton.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. §Savery, G. M., M.A. The College, Harrogate.
1872. *Sawyer, George David, F.R.M.S. 55 Buckingham-place, Brighton.
1887. §SAYCE, Rev. A. H., M.A., Deputy Professor of Comparative Philology in the University of Oxford. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Holly Bank, Halifax, Yorkshire.
1883. ‡Scarisbrick, Charles. 5 Palace-gate, Kensington, London, W.
1884. ‡Scarth, William Bain. Winnipeg, Manitoba, Canada.
1868. §Schacht, G. F. 1 Windsor-terrace, Clifton, Bristol.

Year of Election.

1879. *SCHÄFER, E. A., F.R.S., M.R.C.S., Professor of Physiology in University College, London. 149 Harley-street, London, W.
1883. ‡Schäfer, Mrs. Boreham Wood, Elstree, Herts.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1887. §Schofield, T. Thornfield, Talbot-road, Old Trafford, Manchester.
1883. ‡Schofield, William. Alma-road, Birkdale, Southport.
1885. §Scholes, L. The Limes, Cleveland-road, Manchester.
1887. §Schorlemmer, Carl, F.R.S., Professor of Organic Chemistry in the Owens College, Manchester.
1876. ‡Schuman, Sigismond. 7 Royal Bank-place, Glasgow.
SCHUNCK, EDWARD, Ph.D., F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S., Professor of Applied Mathematics in Owens College, Manchester.
1861. *Schwabe, Edmund Salis. Ryecroft House, Cheetham Hill, Manchester.
1887. §Schwabe, Colonel G. Salis. Portland House, Higher Crumpsall, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec.Z.S. 3 Hanover-square, London, W.
1883. *SCLATER, WILLIAM LUTLEY, B.A., F.Z.S. 3 Hanover-square, London, W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. *Scott, Alexander, M.A., D.Sc. 4 North Bailey, Durham.
1882. ‡Scott, Colonel A. de C., R.E. Ordnance Survey Office, Southampton.
1878. ‡Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. §Scott, Miss Charlotte Angus. Lancashire College, Whalley Range, Manchester.
1876. ‡Scott, Mr. Bailie. Glasgow.
1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.
1886. §Scott, Robert. 161 Queen Victoria-street, London, E.C.
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.R.M.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1884. *Scott, Sydney C. 15 Queen-street, Cheapside, London, E.C.
1858. ‡Scott, William. Holbeck, near Leeds.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1885. ‡Scott-Moncrieff, W. G. The Castle, Banff.
1881. *Scrivener, A. P. Haglis House, Wendover.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1859. ‡Seaton, John Love. The Park, Hull.
1880. ‡SEDGWICK, ADAM, M.A., F.R.S. Trinity College, Cambridge.
1880. ‡SEEBOHM, HENRY, F.L.S., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1861. *SEELEY, HARRY GOVIER, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. The Vine, Sevenoaks.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. §Selim, Adolphus. 21 Mincing-lane, London, E.C.
1885. §Semple, Dr. United Service Club, Edinburgh.
1887. §Semple, James, C., M.R.I.A. 64 Grosvenor-road, Rathmines, Dublin.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.

Year of Election.

1858. *Senior, George, F.S.S. Old Whittington, Chesterfield.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1883. §Seville, Miss M. A. Blythe House, Southport.
1875. §Seville, Thomas. Blythe House, Southport.
1868. ‡Sewell, Philip E. Catton, Norwich.
1883. ‡Shadwell, John Lancelot. 21 Nottingham-place, London, W.
1871. *Shand, James. Parkholme, Elm Park-gardens, London, S.W.
1867. §Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1869. *Shapter, Dr. Lewis, LL.D. 1 Barnfield-crescent, Exeter.
1878. ‡Sharp, David, M.B. Bleckley, Shirley Warren, Southampton.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1886. §Sharp, T. B. French Walls, Birmingham.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
1883. ‡Sharples, Charles H., F.C.S. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1881. *Shaw, H. S. Hele, M.Inst.C.E., Professor of Engineering in University College, Liverpool.
1887. *Shaw, James B. Holly Bank, Cornbrook, Manchester.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Viatoris Villa, Boston, Lincolnshire.
1887. §Shaw, Saville. College of Science, Newcastle-on-Tyne.
1883. ‡Shaw, W. N., M.A. Emmanuel College, Cambridge.
1883. ‡Shaw, Mrs. W. N. Emmanuel House, Cambridge.
1883. ‡Sheard, J. 42 Hoghton-street, Southport.
1883. *Shearer, Miss A. M. Bushy Hill, Cambuslang, Lanark.
1884. ‡Sheldon, Professor J. P. Downton College, near Salisbury.
1878. §Shelford, William, M.Inst.C.E. 35a Great George-street, Westminster, S.W.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡Shenstone, W. A. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
1863. ‡Shepherd, A. B. 17 Great Cumberland-place, Hyde Park, London, W.
1885. ‡Shepherd, Charles. 1 Wellington-street, Aberdeen.
1883. ‡Shepherd, James. Birkdale, Southport.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1883. §Sherlock, David. Lower Leeson-street, Dublin.
1883. §Sherlock, Mrs. David. Lower Leeson-street, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1886. §Shield, Arthur H. 35a Great George-street, London, S.W.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, London, E.C.
1867. ‡Shinn, William C. 4 Varden's-road, Clapham Junction, Surrey, S.W.
1887. *Shipley, Arthur E., M.A. Christ's College, Cambridge.
1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.
1883. ‡Shone, Isaac. Pentrefelin House, Wrexham.
1870. *Shoolbred, James N., M.Inst.C.E., F.G.S. 3 Westminster-chambers, London, S.W.
1875. ‡Shore, Thomas W., F.C.S., F.G.S. Hartley Institution, Southampton.

Year of Election.

1882. ‡SHORE, T. W., jun., M.D., B.Sc. 13 Hill Side, Crouch Hill, London, N.
1881. ‡Shuter, James L. 9 Steele's-road, Haverstock Hill, London, N.W.
1883. §Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Erlesdene, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. Erlesdene, Bowdon, Cheshire.
1885. *SIDGWICK, HENRY, M.A., Litt.D., Professor of Moral Philosophy in the University of Cambridge. Hillside, Chesterton-road, Cambridge.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 12 Queen Anne's-gate, Westminster, S.W.
1878. ‡Sigerson, Professor George, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. ‡Simms, William. The Linen Hall, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1887. *Simon, Henry. Darwin House, Didsbury.
1847. ‡Simon, Sir John, C.B., D.C.L., F.R.S., F.R.C.S., Consulting Surgeon to St. Thomas's Hospital. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1883. §Simpson, Byron R. 7 York-road, Birkdale, Southport.
1887. §Simpson, F. Estacion Central, Buenos Ayres.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
Simpson, William. Bradmore House, Hammersmith, London, W.
1884. **Simpson, W. J. R., M.D. Town House, Aberdeen.*
1887. §Sinclair, Dr. 268 Oxford-street, Manchester.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1884. ‡*Sinclair, Vetch, M.D. 48 Albany-street, Edinburgh.*
1870. *Sinclair, W. P., M.P. 19 Devonshire-road, Prince's Park, Liverpool.
1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta. (Care of Messrs. S. Harraden & Co., 3 Hill's-place, Oxford-street, London, W.)
1865. ‡Sissons, William. 92 Park-street, Hull.
1879. ‡Skertchly, Sydney B. J., F.G.S. 3 Loughborough-terrace, Carshalton, Surrey.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. §Skinner, Provost. Inverurie, N.B.
1870. §SLADEN, WALTER PERCY, F.G.S., F.L.S. Orsett House, Ewell, Surrey.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1884. ‡Slattery, James W. 9 Stephen's-green, Dublin.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S., F.G.S. Clifton, Bristol.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1860. ‡Sloper, S. Elgar. Winterton, near Hythe, Southampton.

Year of Election.

1867. ‡Small, David. Gray House, Dundee.
1887. §Small, E. W. 11 Arthur-street, Nottingham.
1887. §Small, William. Cavendish-crescent North, The Park, Nottingham.
1881. ‡Smallshan, John. 81 Manchester-road, Southport.
1885. §Smart, James. Valley Works, Brechin, N.B.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. §Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1876 ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smieton, John G. 3 Polworth-road, Coventry Park, Streatham, London, S.W.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, London, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, London, S.W.
1887. §Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.
1865. ‡SMITH, DAVID, F.R.A.S. 40 Bennett's-hill, Birmingham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1886. ‡Smith, E. O. Council House, Birmingham.
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.
1866. *Smith, F. C. Bank, Nottingham.
1887. §Smith, Rev. F. J., M.A. Trinity College, Oxford.
1855. ‡Smith, George. Port Dundas, Glasgow.
1885. ‡Smith, Rev. G. A., M.A. 91 Fountainhall-road, Aberdeen.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, London, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 54 West Nile-street, Glasgow.
1874. ‡Smith, John Haigh. 77 Southbank-road, Southport.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1871. ‡Smith, J. William Robertson, M.A., Lord Almoner's Professor of Arabic in the University of Cambridge.
1883. ‡Smith, M. Holroyd. Fern Hill, Halifax.
1886. *Smith, Mrs. Hencotes House, Hexham.
1860. *SMITH, PROTHEROE, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1885. ‡SMITH, ROBERT H., M.Inst.C.E., Professor of Engineering in the Mason Science College, Birmingham.
1840. *Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1885. *Smith, Watson. 147 High-street, Chorlton-on-Medlock, Manchester.
1887. §Smith, Dr. Wilberforce. 14 Stratford-place, London, W.

Year of Election.

1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡Smithells, Arthur, B.Sc., Professor of Chemistry in the Yorkshire College, Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1878. ‡Smithson, Joseph S. Balnagowan, Rathmines, Co. Dublin.
1882. §Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *SMYTH, CHARLES PIAZZI, F.R.S.E., F.R.A.S., Astronomer Royal for Scotland, Professor of Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1883. ‡Smyth, Rev. Christopher. Woodford Rectory, Thrapston.
1874. ‡Smyth, Henry. Downpatrick, Ireland.
1878. §Smyth, Mrs. Isabella. Wigmore Lodge, Cullenswood-avenue, Dublin.
1857. *SMYTH, JOHN, jun., M.A., F.R.M.S. Milltown, Banbridge, Ireland.
1864. ‡SMYTH, Sir WARINGTON W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 5 Inverness-terrace, Bayswater, London, W.
1854. ‡Smythe, General W. J., R.A., F.R.S. Athenæum Club, Pall Mall, London, S.W.
1883. ‡*Snape, Joseph.* 13 *Scarisbrick-street, Southport.*
1887. §Snell, Bernard J. 5 Park-place, Broughton, Manchester.
1878. §Snell, H. Saxon. 22 Southampton-buildings, London, W.C.
1879. *SOLLAS, W. J., M.A., D.Sc., F.R.S.E., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Sheffield.
1886. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1887. §Sowerbutts, Eli. Market-place, Manchester.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1863. *Spark, H. King. Starforth House, Barnard Castle.
1869. *Spence, J. Berger. 31 Lombard-street, London, E.C.
1887. §Spencer, F. M. Fernhill, Knutsford.
1881. ‡Spencer, Herbert E. Lord Mayor's Walk, York.
1884. §Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1861. ‡Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. Springbank, Old Trafford, Manchester.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1875. ‡Spencer, W. H. Richmond Hill, Clifton, Bristol.
1884. *Spice, Robert Paulson, M.Inst.C.E. 21 Parliament-street, Westminster, S.W.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, London, S.W.
1864. *Spottiswoode, W. Hugh, F.C.S. 41 Grosvenor-place, London, S.W.
1854. *SPRAGUE, THOMAS BOND, M.A., F.R.S.E. 29 Buckingham-terrace, Edinburgh.

Year of Election.

1883. §Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1853. ‡Spratt, Joseph James. West Parade, Hull.
1884. *Spruce, Samuel. Beech House, Tamworth.
Square, Joseph Elliot. 147 Maida Vale, London, W.
1877. ‡SQUARE, WILLIAM, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.
*Squire, Lovell. 6 Heathfield-terrace, Chiswick, Middlesex.
1879. ‡Stacye, Rev. John. Shrewsbury Hospital, Sheffield.
1858. *STAINTON, HENRY T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, S.E.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1883. *Stanford, Edward, jun., F.R.G.S. 17 Spring-gardens, London, S.W.
1865. ‡STANFORD, EDWARD C. C., F.C.S. Glenwood, Dalmuir, N.B.
1837. Staniforth, Rev. Thomas. Storrs, Windermere.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, Surrey, S.E.
1883. §Stanley, Mrs. Cumberlow, South Norwood, Surrey, S.E.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1883. ‡Stapley, Alfred M. Marion-terrace, Crewe.
1866. ‡*Starey, Thomas R. Daybrook House, Nottingham.*
1876. §Starling, John Henry, F.C.S. The Avenue, Erith, Kent.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. Saltaire, Bradford, Yorkshire.
1881. ‡Stead, W. H. Orchard-place, Blackwall, London, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, London, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1887. §Steinthal, S. Alfred. 81 Nelson-street, Manchester.
1887. §Stelfox, John L. 6 Hilton-street, Oldham, Manchester.
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Lowville (P.O.), State of New York, U.S.A.
1879. *STEPHENSON, HENRY, J.P. Endcliffe Vale, Sheffield.
1881. ‡Stephenson, J. F. 3 Mount-parade, York.
1876. ‡Steuart, Walter. City Bank, Pollockshaws, near Glasgow.
1870. *Stevens, Miss Anna Maria. 1 Sinclair-road, West Kensington, London, W.
1880. *Stevens, J. Edward. 16 Woodlands-terrace, Swansea.
1886. §Stevens, Marshall. Highfield House, Urmstone, near Manchester.
1868. ‡Stevenson, Henry, F.L S. Newmarket-road, Norwich.
1878. ‡Stevenson, Rev. James, M.A. 21 Garville-avenue, Rathgar, Dublin.
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1887. **Stewart, A. H. Heather-lane, Bowdon, Manchester.*
1882. ‡Steward, Rev. C. E., M.A. The Polygon, Southampton.
1885. ‡Stewart, Rev. Alexander. Heathcot, Aberdeen.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1885. ‡Stewart, David. 293 Union-street, Aberdeen.
1886. *Stewart, Duncan. Kelvinside, Glasgow.
1887. §Stewart, George N. Physiological Laboratory, Owens College, Manchester.
1875. *Stewart, James, B.A., M.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.

Year of Election.

1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1883. *STOCKER, W. R. Cooper's Hill, Staines.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
1845. *STOKES, GEORGE GABRIEL, M.P., M.A., D.C.L., LL.D., Pres. R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1887. §Stone, E. D., F.C.S. The Depleach, Cheadle, Cheshire.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1886. ‡Stone, J. B. The Grange, Erdington, Birmingham.
1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 11 Sheffield-gardens, Kensington, London, W.
1876. ‡Stone, Octavius C., F.R.G.S. Springfield, Nuneaton.
1883. §Stone, Thomas William. 189 Goldhawk-road, Shepherd's Bush, London, W.
1859. ‡STONE, Dr. WILLIAM H. 14 Dean's-yard, Westminster, S.W.
1857. ‡STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
1878. *Stoney, G. Gerald. 9 Palmerston Park, Dublin.
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. 9 Palmerston Park, Dublin.
1876. §Stopes, Henry, F.G.S. Kenwyn, Cintra Park, Upper Norwood, S.E.
1883. §Stopes, Mrs. Kenwyn, Cintra Park, Upper Norwood, S.E.
1854. ‡Store, George. Prospect House, Fairfield, Liverpool.
1887. §Storer, Edwin. Woodlands, Crumpsall, Manchester.
1887. *Storey, H. L. Lancaster.
1873. ‡Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1884. §Storrs, George H. Fern Bank, Stalybridge.
1859. §Story, Captain James Hamilton. 17 Bryanston-square, London, W.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General RICHARD, R.E., C.S.I., F.R.S., Pres.R.G.S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, London, W.
1881. ‡Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.
1881. ‡Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, London, S.W.
*Strickland, Charles. 21 Fitzwilliam-place, Dublin.
1879. ‡Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.
Strickland, William. French Park, Roscommon, Ireland.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1883. §Strong, Henry J., M.D. Whitgift House, Croydon.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1887. *Stroud, Professor H. College of Science, Newcastle-on-Tyne.
1887. *Stroud, William, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
1876. *STRUTHERS, JOHN, M.D., LL.D., Professor of Anatomy in the University of Aberdeen.

Year of Election.

1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. High School, Newcastle, Staffordshire.
1872. *Stuart, Rev. Edward A., M.A. 116 Grosvenor-road, Highbury New Park, London, N.
1886. ‡Stuart, G. Morton, M.A. East Harptree, near Bristol.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1885. §Stump, Edward C. 26 Parkfield-street, Moss-lane East, Manchester.
1879. *Styring, Robert. 3 Hartshead, Sheffield.
1857. ‡Sullivan, William K., Ph.D., M.R.I.A. Queen's College, Cork.
1883. ‡Summers, William, M.P. Sunnyside, Ashton-under-Lyne.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. §Sumpner, W. E. 37 Pennyfields, Poplar, London, E.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne,
1862. *Sutherland, George Granville William, Duke of, K.G., F.R.S., F.R.G.S. Stafford House, London, S.W.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1884. ‡Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡Sutton, Francis, F.C.S. Bank Plain, Norwich.
1881. ‡Sutton, William. Town Hall, Southport.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
1881. §Swan, Joseph Wilson, M.A. Mosley-street, Newcastle-on-Tyne.
1861. *Swan, Patrick Don S. Kirkcaldy, N.B.
1862. *Swan, William, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews, N.B.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1883. ‡Sweeting, Rev. T. E. 50 Roe-lane, Southport.
1887. §Swinburne, James. Shona, Chelmsford.
1870. *Swinburne, Sir John, Bart., M.P. Capheaton, Newcastle-on-Tyne.
1863. ‡*Swindell, J. S. E. Summerhill, Kingswinford, Dudley.*
1885. ‡Swindells, Miss. Springfield House, Ilkley, Yorkshire.
1887. *Swindells, Rupert, F.R.G.S. Wilton Villa, The Firs, Bowdon, Cheshire.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1858. ‡Sydney, The Right Rev. Alfred Barry, Bishop of, D.D., D.C.L. Sydney.
1883. ‡Sykes, Alfred. Highfield, Huddersfield.
1873. §Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1887. *Sykes, George H. 12 Albert-square, Clapham, London, S.W.
1862. ‡Sykes, Thomas. Cleckheaton.
1887. *Sykes, T. H. Cheadle, Cheshire.
Sylvester, James Joseph, M.A., D.C.L., LL.D., F.R.S., Savilian Professor of Geometry in the University of Oxford. Oxford.
1870. ‡Symes, Richard Glascott, B.A., F.G.S. Geological Survey of Ireland, 14 Hume-street, Dublin.
1885. §Symington, Johnson, M.D. 2 Greenhill Park, Edinburgh.
1881. *Symington, Thomas. Wardie House, Edinburgh.
1856. *Symonds, Frederick, M.A., F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1859. §Symons, G. J., F.R.S., Sec.R.Met.Soc. 62 Camden-square, London, N.W.
1883. ‡Symons, Simon. Belfast House, Farquhar-road, Norwood, S.E.

Year of Election.

1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
1886. §Symons, W. H., F.C.S., F.R.M.S. 130 Fellowes-road, Hampstead, London, N.W.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
1872. ‡Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, London, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1877. *TAIT, LAWSON, F.R.C.S. The Crescent, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡*Tait, P. M., F.R.G.S., F.S.S. Oriental Club, Hanover-square, London, W.*
1883. §Tapscott, R. L. 41 Parkfield-road, Prince's Park, Liverpool.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. Ferniebrae, Dean Park, Bournemouth.
1857. *Tate, Alexander. Longwood, Whitehouse, Belfast.
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1876. ‡*Tatlock, Robert R. 26 Burnbank-gardens, Glasgow.*
1879. ‡Tattershall, William Edward. 15 North Church-street, Sheffield.
1886. ‡Taunton, Richard. Brook Vale, Witton.
1878. *Taylor, A. Claude. North Circus-street, Nottingham.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1887. §Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1887. §Taylor, George Spratt, F.C.S. 13 Queen's-terrace, St. John's Wood, London, N.W.
1881. *Taylor, H. A. 25 Collingham-road, South Kensington, London, S.W.
1884. *Taylor, H. M., M.A. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. 17 Castlegate, Nottingham.
1887. §Taylor, Rev. Canon Isaac, D.D. Settrington Rectory, York.
1879. ‡Taylor, John. Broomhall-place, Sheffield.
1861. *Taylor, John, M.Inst.C.E., F.G.S. 29 Portman-square, London, W.
1873. ‡TAYLOR, JOHN ELLOR, Ph.D., F.L.S., F.G.S. The Mount, Ipswich.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1883. ‡Taylor, Michael W., M.D. Hatton Hall, Penrith.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1878. ‡Taylor, Robert, J.P., LL.D. Corballis, Drogheda.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡Taylor, Rev. S. B., M.A. Whixley Hall, York.
1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1887. §Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1884. ‡Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1885. §Teall, J. J. H., M.A., F.G.S. 12 Cumberland-road, Kew, Surrey.
1869. ‡Teesdale, C. S. M. Whyke House, Chichester.
1876. *Temperley, Ernest, M.A. Queen's College, Cambridge.
1879. ‡Temple, Lieutenant George T., R.N., F.R.G.S. The Nash, near Worcester.

Year of Election.

1880. §TEMPLE, Sir RICHARD, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., M.P., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
1882. §Terrill, William. 3 Hanover-street, Swansea.
1881. ‡Terry, Mr. Alderman. Mount-villas, York.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1887. §Tetlow, T. 273 Stamford-street, Ashton-under-Lyne.
1882. *Thane, George Dancer, Professor of Anatomy in University College, Gower-street, London, W.C.
1885. ‡Thin, Dr. George, 22 Queen Anne-street, London, W.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., C.M.G., M.A., B.Sc., F.R.S., F.L.S. Royal Gardens, Kew.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1875. *THOMAS, CHRISTOPHER JAMES. Drayton Lodge, Redland, Bristol.
1883. ‡Thomas, Ernest C., B.A. 13 South-square, Gray's Inn, London, W.C.
1884. ‡THOMAS, F. WOLFERSTAN. Molson's Bank, Montreal, Canada.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. Ivor House, Redlands, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1881. §THOMAS, J. BLOUNT. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1880. *Thomas, Joseph William, F.C.S. The Laboratory, West Wharf, Cardiff.
1883. ‡Thomas, P. Bossley. 4 Bold-street, Southport.
1883. §Thomas, Thomas H. 45 The Walk, Cardiff.
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886. §Thomasson, Yeoville. 9 Observatory-gardens, Kensington, London, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1887. §Thompson, C. St. Mary's Hospital, London, W.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1885. §Thompson, D'Arcy W., B.A., Professor of Physiology in University College, Dundee. University College, Dundee.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1883. *Thompson, Francis. 1 Avenue-villas, St. Peter's-road, Croydon.
1859. ‡Thompson, George, jun. Pitmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
1883. *Thompson, Henry G., M.D. 8 Addiscombe-villas, Croydon.
Thompson, Henry Stafford. Fairfield, near York.
1883. *Thompson, Isaac Cooke, F.L.S., F.R.M.S. Woodstock, Waverley-road, Liverpool.
1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley Hill.
1873. ‡Thompson, M. W. Guiseley, Yorkshire.
1876. *Thompson, Richard. Park-street, The Mount, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.
1874. ‡Thompson, Robert. Walton, Fortwilliam Park, Belfast.
1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.A.S., Professor of Physics in the City and Guilds of London Institute, Finsbury Technical Institute, E.C.

Year of Election.

1884. ‡Thompson, Sydney de Courcy. 16 Canonbury-park South, London, N.
1883. *Thompson, T. H. Heald Bank, Bowdon, Manchester.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
Thomson, Guy. Oxford.
1850. *THOMSON, Professor JAMES, M.A., LL.D., D.Sc., F.R.S. L. & E. 2 Florentine-gardens, Hillhead-street, Glasgow.
1868. §THOMSON, JAMES, F.G.S. 3 Abbotsford-place, Glasgow.
1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.
1883. ‡THOMSON, J. J., M.A., F.R.S., Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1871. *THOMSON, JOHN MILLAR, F.C.S., Professor of Chemistry in King's College, London, W.C.
1886. ‡Thomson, Joseph. Thornhill, Dumfriesshire.
1871. ‡*Thomson, Robert, LL.B.* 12 *Rutland-square, Edinburgh.*
1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., F.R.S. L. & E., F.R.A.S., Professor of Natural Philosophy in the University of Glasgow. The University, Glasgow.
1877. *Thomson, Lady. The University, Glasgow.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helen's.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thornburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1886. §Thornley, J. E. Lyndon, Bickenhill, near Birmingham.
1887. §Thornton, John. 3 Park-street, Bolton.
1867. ‡Thornton, Thomas. Dundee.
1883. §Thorowgood, Samuel. Castle-square, Brighton.
1845. ‡Thorp, Dr. Disney. Lyppiatt Lodge, Suffolk Lawn, Cheltenham.
1881. ‡Thorp, Fielden. Blossom-street, York.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
1881. *Thorp, Josiah. 159 Field-street, Liverpool.
1864. **Thorp, William, B.Sc., F.C.S.* 39 *Sandringham-road, Kingsland, London, E.*
1871. ‡THORPE, T. E., Ph.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the Normal School of Science. Science Schools. South Kensington, London, S.W.
1883. §Threlfall, Henry Singleton. 5 Prince's-street, Southport.
1883. ‡Thresh, John C., D.Sc. The Willows, Buxton.
1868. ‡THUILLIER, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S 11 Sussex-gardens, Hyde Park, London, W.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1884. §TIDY, CHARLES MEYMOTT, M.D. 3 Mandeville-place, Cavendish-square, London, W.
1874. ‡TILDEN, WILLIAM A., D.Sc., F.R.S., F.C.S., Professor of Chemistry and Metallurgy in the Mason Science College, Birmingham. 36 Frederick-road, Birmingham.
1873. ‡Tilghman, B. C. Philadelphia, U.S.A.
1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.
1883. ‡Tillyard, Mrs. Fordfield, Cambridge.
Tinker, Ebenezer. Mealhill, near Huddersfield.
1865. ‡Timmins, Samuel, J.P., F.S.A. Hill Cottage, Fillongley, Coventry.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1887. §Tolmé, Mrs. Melrose House, Higher Broughton, Manchester.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1856. ‡*Tomes, Robert Fisher. Littleton, Worcestershire.*

Year of Election.

1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 7 North-road, Highgate, London, N.
1887. §Tonge, Rev. Canon. Chorlton-cum-Hardy, Manchester.
1887. §Tonge, James. Woodbine House, West Houghton, Bolton.
1865. ‡Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. *Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1887. §Topham, F. 15 Great George-street, London, S.W.
1861. *Topham, John, A.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872. *TOPLEY, WILLIAM, F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1886. §Topley, Mrs. W. Hurstbourne, Elgin-road, Croydon.
1875. §Torr, Charles Hawley. 7 Regent-street, Nottingham.
1886. ‡Torr, Charles Walker. Cambridge-street Works, Birmingham.
1884. ‡Torrance, John F. Folly Lake, Nova Scotia, Canada.
1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.
1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. Avenue House, Cotham Park, Bristol.
1883. ‡Townsend, Francis Edward. 19 Aughton-road, Birkdale, Southport.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1877. ‡Tozer, Henry. Ashburton.
1876. *TRAIL, Professor J. W. H., M.A., M.D., F.L.S. University of Aberdeen, Old Aberdeen.
1883. ‡TRAILL, A., M.D., LL.D. Ballylough, Bushmills, Ireland.
1870. ‡TRAILL, WILLIAM A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1883. ‡Traill, Mrs. Portrush, Ireland.
1875. ‡Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡TRAQUAIR, RAMSAY H., M.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
Tregelles, Nathaniel. Liskeard, Cornwall.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1884. ‡Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.
1884. §Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1877. ‡TRIMEN, HENRY, M.B., F.L.S. British Museum, London, S.W.
1871. ‡TRIMEN, ROLAND, F.R.S., F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §TRISTRAM, Rev. HENRY BAKER, D.D., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1884. *Trotter, Alexander Pelham. 53 Addison Mansions, Blythe-road, West Kensington, London, W.
1885. §Trotter, Coutts. 17 Charlotte-square, Edinburgh.
1887. *Trouton, Frederick T. Trinity College, Dublin.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1885. *Tubby, A. H. Guy's Hospital, London, S.E.

Year of Election.

1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
Tuke, James H. Bancroft, Hitchin.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1887. §Tuke, W. C. 29 Princess-street, Manchester.
1883. ‡TUPPER, The Hon. Sir CHARLES, G.C.M.G., C.B., High Commissioner for Canada. 9 Victoria-chambers, London, S.W.
1854. ‡*Turnbull, James, M.D. 86 Rodney-street, Liverpool.*
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1871. ‡Turnbull, William, F.R.S.E. Menslaws, Jedburgh, N.B.
1873. *Turner, George. Horton Grange, Bradford, Yorkshire.
1882. ‡Turner, G. S. 9 Carlton-crescent, Southampton.
1883. ‡Turner, Mrs. G. S. 9 Carlton-crescent, Southampton.
1875. ‡*Turner, Thomas, F.S.S. Ashley House, Kingsdown, Bristol.*
1886. *Turner, Thomas, M.A. Mason Science College, Birmingham.
1863. *TURNER, Sir WILLIAM, M.B., F.R.S. L. & E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1883. ‡Turrell, Miss S. S. High School, Redland-grove, Bristol.
1884. *Tutin, Thomas. Weston-on-Trent, Derby.
1842. Twamley, Charles, F.G.S. Ryton-on-Dunsmore, Coventry.
1884. *Tweddell, Ralph Hart. Provender, Faversham, Kent.
1886. *Twigg, G. H. Church-road, Moseley, Birmingham.
1847. ‡TWISS, Sir TRAVERS, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1882. §Tyer, Edward. Horneck, Fitzjohn's-avenue, Hampstead, London, N.W.
1865. ‡TYLOR, EDWARD BURNETT, D.C.L., LL.D., F.R.S., Keeper of the University Museum, Oxford.
1858. *TYNDALL, JOHN, D.C.L., LL.D., Ph.D., F.R.S., F.G.S. Hon. Professor of Natural Philosophy in the Royal Institution, London. Hindhead House, Hindhead, Surrey.
1883. ‡Tyrer, Thomas, F.C.S. Garden-wharf, Battersea, London, S.W.
1861. *Tysoe, John. 28 Heald-road, Bowdon, near Manchester.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1886. ‡Underhill, Thomas, M.D. West Bromwich.
1885. ‡Unwin, Howard. Newton-grove, Bedford Park, Chiswick, London.
1883. §Unwin, John. Park-crescent, Southport.
1883. §Unwin, William Andrews. The Briars, Freshfield, near Liverpool.
1876. *UNWIN, W. C., F.R.S., M.Inst.C.E., Professor of Engineering at the Central Institute, City and Guilds of London. 7 Palace-gate Mansions, Kensington, London, W.
1887. §Upton, Francis R. Orange, New Jersey, U.S.A.
1872. ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, London, S.W.

1885. ‡Vachell, Charles Tanfield, M.D. Cardiff.
1887. §Vaizey, J. Reynolds. Broxbourne, Herts.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1884. ‡Van Horne, W. C. Dorchester-street West, Montreal, Canada.
1883. *VanSittart, The Hon. Mrs. A. A. 11 Lypiatt-terrace, Cheltenham.

Year of Election.

1886. ‡Vardy, Rev. A. R., M.A. King Edward's School, Birmingham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *Varley, S. Alfred. 2 Hamilton-road, Highbury Park, London, N.
1870. ‡Varley, Mrs. S. A. 2 Hamilton-road, Highbury Park, London, N.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. §Vasey, Charles. 112 Cambridge-gardens, London, W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §Veley, V. H., M.A., F.C.S. University College, Oxford.
1873. *Verney, Captain Edmund H., R.N., F.R.G.S. Rhianva, Bangor, North Wales.
1883. *Verney, Mrs. Rhianva, Bangor, North Wales.
Verney, Sir Harry, Bart., M.P. Lower Claydon, Buckinghamshire.
Vernon, George John, Lord. Sudbury Hall, Derbyshire.
1883. ‡Vernon, H. H., M.D. York-road, Birkdale, Southport.
1864. *Vicary, William, F.G.S. The Priory, Colleton-crescent, Exeter.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1883. ‡Vines, Sydney Howard, M.A., D.Sc., F.R.S., F.L.S. 66 Hills-road, Cambridge.
1856. ‡Vivian, Edward, M.A. Woodfield, Torquay
*Vivian, Sir H. Hussey, Bart., M.P., F.G.S. Park Wern-Swansea; and 27 Belgrave-square, London, S.W.
1884. ‡*Von Linden, François Hermann. Amsterdam, Holland.*
1869. ‡Vose, Dr. James. Gambier-terrace, Liverpool.

1886. *Wackrill, Samuel Thomas, J.P. Leamington.
1860. §Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1884. ‡Wait, Charles E. Rolla, Missouri, U.S.A.
1886. ‡Waite, J. W. The Cedars, Bestcot, Walsall.
1879. *Wake, Bernard. Abbeyfield, Sheffield.
1870. §Wake, Charles Staniland. Welton, near Brough, East Yorkshire.
1884. ‡Waldstein, Charles, M.A., Ph.D., Director of the Fitzwilliam Museum, Cambridge. Cambridge.
1873. ‡Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.
1882. *Walkden, Samuel. The Thorne, Bexhill, near Hastings, Sussex.
1885. ‡Walker, Baillie. 52 Victoria-street, Aberdeen.
1885. §Walker, Charles Clement, F.R.A.S. Lilliesball Old Hall, Newport, Shropshire.
1883. §Walker, Mrs. Emma. 14 Bootham-terrace, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
Walker, Frederick John. The Priory, Bathwick, Bath.
1883. ‡Walker, George. 11 Hamilton-square, Birkenhead, Liverpool.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1885. §Walker, General J. T., C.B., R.E., LL.D., F.R.S., F.R.G.S. 13 Cromwell-road, London, S.W.
1866. *Walker, John Francis, M.A., F.C.S., F.G.S., F.L.S. 16 Gillygate, York.
1881. ‡Walker, John Sydenham. 83 Bootham, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1886. *Walker, Major Philip Billingsley. Sydney, New South Wales.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, London, S.E.
1887. §Walker, T. A. 15 Great George-street, London, S.W.
1883. §Walker, Thomas A. 66 Leyland-road, Southport.

Year of Election.

Walker, William. 47 Northumberland-street, Edinburgh.
1881. *Walker, William. 14 Bootham-terrace, York.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, F.L.S., F.R.G.S. Nutwood Cottage, Frith Hill, Godalming.
1883. §Wallace, George J. Hawthornbank, Dunfermline.
1859. ‡WALLACE, WILLIAM, Ph.D., F.C.S. Chemical Laboratory, 138 Bath-street, Glasgow.
1887. *Waller, Augustus, M.D. Weston Lodge, 16 Grove End-road, London, N.W.
1862. ‡Wallich, George Charles, M.D., F.L.S., F.R.G.S. 26 Addison-road North, Notting Hill, London, W.
1886. ‡Walliker, Samuel. Grandale, Westfield-road, Edgbaston, Birmingham.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. §Wallis, Herbert. Redpath-street, Montreal, Canada.
1886. ‡Wallis, Whitworth. Westfield, Westfield-road, Edgbaston, Birmingham.
1883. ‡Walmesley, Oswald. Shevington Hall, near Wigan.
1887. *Walmsley, Miss Isabella. 1 Wynnstay-terrace, Stretford-road, Old Trafford, Manchester.
1887. §Walmsley, J. Winton, Patricroft, Manchester.
1883. ‡Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., F.R.S. Ealing, Middlesex, W.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1863. ‡Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.
1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.
1872. ‡Warburton, Benjamin. Leicester.
1887. §Ward, A. W., M.A., Litt.D., Professor of History and English Literature in Owens College, Manchester.
1874. ‡Ward, F. D., J.P., M.R.I.A. Clonaver, Strandtown, Co. Down.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡Ward, H. Marshall, M.A., F.L.S., Professor of Botany in the Royal Indian Civil Engineering College, Cooper's Hill, Egham.
1874. §Ward, John, F.S.A., F.G.S., F.R.G.S. Lenoxvale, Belfast.
1887. §Ward, John, F.G.S. 23 Stafford-street, Longton, Manchester.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. 5 Holtham-road, St. John's Wood, London, N.W.
1884. *Ward, John William. Newstead, Halifax.
1883. ‡Ward, Thomas, F.C.S. Arnold House, Blackpool.
1887. §Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1884. §Wardwell, George J. Rutland, Vermont, U.S.A.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida Vale, London, W.
1887. *Waring, Richard S. Pittsburg, Pennsylvania, U.S.A.
1878. §WARINGTON, ROBERT, F.R.S., F.C.S. Harpenden, St. Albans, Herts.
1882. ‡Warner, F. W., F.L.S. 20 Hyde-street, Winchester.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1875. ‡Warren, Algernon. Naseby House, Pembroke-road, Clifton, Bristol.
1887. §WARREN, Colonel Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. 44 St. George's-road, London, S.W.

Year of Election.

1856. ‡Washbourne, Buchanan, M.D. Gloucester.
1876. ‡*Waterhouse, A. Willenhall House, Barnet, Herts.*
1875. *Waterhouse, Lieut.-Colonel J. 40 Hamilton-terrace, London, N.W.
1854. ‡Waterhouse, Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1881. §Watherston, E. J. 12 Pall Mall East, London, S.W.
1887. §Watkin, F. W. 46 Auriol-road, West Kensington, London, W.
1884. ‡Watson, A. G., D.C.L. The School, Harrow, Middlesex.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1886. *Watson, C. J. 34 Smallbrook-street, Birmingham.
1883. ‡Watson, C. Knight, M.A. Society of Antiquaries, Burlington House, London, W.
1867. ‡*Watson, Frederick Edwin. Thickthorne House, Cringleford, Norwich.*
1885. §Watson, Deputy Surgeon-General G. A. 4 St. Margaret's-terrace, Cheltenham.
1882. ‡WATSON, Rev. H. W., D.Sc., F.R.S. Berkeswell Rectory, Coventry.
1873. *Watson, Sir James. 9 Woodside-terrace, Glasgow.
1887. §Watson, J. Beauchamp. Gilt Hall, Carlisle.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. ‡Watson, Thomas Donald. 23 Cross-street, Finsbury, London, E.C.
1882. ‡Watt, Alexander. 89 Hartington-road, Sefton Park, Liverpool.
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E., F.R.G.S. Ashley-avenue, Belfast.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1883. §Watts, W. W., M.A., F.G.S. Broseley, Shropshire.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1859. ‡Waugh, Edwin. New Brighton, near Liverpool.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1886. §Webber, Major-General C. E., C.B. 112 Belvedere-road, London, S.E.
1859. ‡Webster, John. Edgehill, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1882. *Webster, Sir Richard Everard, Q.C., M.P. Hornton Lodge, Hornton-street, Kensington, London, S.W.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. Karlsruhe.
1854. ‡Weightman, William Henry. Fern Lea, Seaforth, Liverpool.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.

Year of Election.

1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, London, S.W.
1876. *Weldon, W. F. R., M.A. 14 Brookside, Cambridge.
1880. *Weldon, Mrs. 14 Brookside, Cambridge.
1881. ‡Wellcome, Henry S. First Avenue Hotel, Holborn, London, W.C.
1879. §Wells, Charles A. Lewes; and 45 Springfield-road, Brighton.
1881. ‡Wells, Rev. Edward, B.A. West Dean Rectory, Salisbury.
1883. ‡*Wells, G. I. J. Cressington Park, Liverpool.*
1883. ‡Welsh, Miss. Girton College, Cambridge.
1887. *Welton, T. A. Rectory House-grove, Clapham, London, S.W.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
1881. *Wenlock, The Right Hon. Lord. 8 Great Cumberland-place, London, W.; and Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.
1886. §Wertheimer, J., B.A., B.Sc., F.C.S. 32 Lyddon-terrace, Leeds.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1870. ‡West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1870. *Westgarth, William. 10 Bolton-gardens, South Kensington, London, S.W.
1882. §Westlake, Ernest, F.G.S. Fordingbridge, Hants.
1882. ‡Westlake, Richard. Portswood, Southampton.
1882. ‡Westlake, W. C. Grosvenor House, Southampton.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1875. *Weston, Sir Joseph D. Dorset House, Clifton Down, Bristol.
1864. ‡Westropp, W. H. S., M.R.I.A. Lisdoonvarna, Co. Clare.
1860. ‡Westwood, John O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1882. §Wethered, Edward, F.G.S. 5 Berkeley-place, Cheltenham.
1884. ‡Wharton, E. R., M.A. 4 Broad-street, Oxford.
1885. *Wharton, Captain W. J. L., R.N., F.R.S., F.R.G.S. Florys, Prince's-road, Wimbledon Park, Surrey.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.
1884. ‡Wheeler, Claude L. 123 Metcalfe-street, Montreal, Canada.
1847. ‡*Wheeler, Edmund, F.R.A.S.* 48 *Tollington-road, Holloway, London, N.*
1883. *Wheeler, George Brash. Elm Lodge, Wickham-road, Beckenham, Kent.
1878. *Wheeler, W. H., M.Inst.C.E. Boston, Lincolnshire.
1883. ‡Whelpton, Miss K. Newnham College, Cambridge.
1879. *Whidborne, Rev. George Ferris, M.A., F.G.S. Charante, Torquay.
1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. Kew Observatory, Richmond, Surrey.
1884. ‡Whischer, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1887. §Whitaker, E. J. Burnley, Lancashire.
1874. ‡Whitaker, Henry, M.D. 33 High-street, Belfast.
1883. ‡Whitaker, T. Helm View, Halifax.

Year of Election.

1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.; and 33 East Park-terrace, Southampton.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyleshire.
1886. ‡White, A. Silva, Secretary to the Scottish Geographical Society, Edinburgh.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1882. ‡White, Rev. George Cecil, M.A. St. Paul's Vicarage, Southampton.
1885. *White, J. Martin. Spring Grove, Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡WHITE, JOHN FORBES. 311 Union-street, Aberdeen.
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡White, Laban. Blandford, Dorset.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 365 Euston-road, London, N.W.
1883. *White, Mrs. 365 Euston-road, London, N.W.
1886. §White, William. 4 Mecklenburgh-square, London, W.C.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. * *Whitehead, Peter Ormerod. 25 Peel-avenue, Ardwick, Manchester.*
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1855. *Whitehouse, Wildeman W. O. 18 Salisbury-road, West Brighton.
1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
1884. §Whiteley, Joseph. Huddersfield.
1881. §Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1866. ‡Whitfield, Samuel. Eversfield, Eastnor-grove, Leamington.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Charles Thomas, M.A., F.R.A.S. Bedlington, Morpeth.
1857. * *Whitty, Rev. John Irwine, M.A., D.C.L., LL.D. 92 Mortimer-street, Herne Bay, Kent.*
1887. §Whitwell, William. Overdene, Saltburn-by-the-Sea.
1874. *Whitwill, Mark. Redland House, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡WHITWORTH, Rev. W. ALLEN, M.A. Glenthorne-road, Hammersmith, London, W.
1887. §Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *Wilde, Henry, F.R.S. The Hurst, Alderley Edge, Manchester.
1865. ‡Wiggin, Henry, M.P. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1885. ‡Wigglesworth, Alfred. Gordondale House, Aberdeen.
1881. *Wigglesworth, James. New Parks House, Falsgrave, Scarborough.
1883. ‡Wigglesworth, Mrs. New Parks House, Falsgrave, Scarborough.
1881. *Wigglesworth, Robert. Harrogate Club, Harrogate.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1883. ‡Wigner, G. W. Plough-court, 37 Lombard-street, London, E.C.
1884. ‡ *Wilber, Charles Dana, LL.D. Grand Pacific Hotel, Chicago, U.S.A.*
1881. ‡WILBERFORCE, W. W. Fishergate, York.
1887. §Wilkinson, C. H. Slaithwaite, near Huddersfield.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1886. *Wilkinson, J. H. Corporation-street, Birmingham.
1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. The Polygon, Ardwick, Manchester.

Year of Election.

1872. ‡Wilkinson, William. 168 North-street, Brighton.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay.
1859. ‡Willet, John, M.Inst.C.E. 35 Albyn-place, Aberdeen.
1872. ‡WILLETT, HENRY, F.G.S. Arnold House, Brighton.
WILLIAMS, CHARLES JAMES B., M.D., F.R.S. 47 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Charles Theodore, M.A., M.B. 47 Upper Brook-street, Grosvenor-square, London, W.
1887. §Williams, E. Leader, M.Inst.C E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 1 Gorse-lane, Swansea.
1875. *Williams, Rev. Herbert A., M.A. S.P.G. College, Trichinopoly, India.
1883. ‡Williams, Rev. H. A. The Ridgeway, Wimbledon, Surrey.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1887. §Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
1870. §WILLIAMS, JOHN, F.C.S. 63 Warwick-gardens, Kensington, London, W.
1875. *Williams, M. B. Killay House, near Swansea.
1879. ‡WILLIAMS, MATTHEW W., F.C.S. Queenwood College, Stockbridge, Hants.
1886. §Williams, Richard, J.P. Brunswick House, Wednesbury.
Williams, Robert, M.A. Bridehead, Dorset.
1883. ‡Williams, R. Price. North Brow, Primrose Hill, London, N.W.
1869. ‡WILLIAMS, Rev. STEPHEN. Stonyhurst College, Whalley, Blackburn.
1883. §Williams, T. H. 2 Chapel-walk, South Castle-street, Liverpool.
1883. §Williams, T. Howell. 125 Fortess-road, London, N.W.
1877. *WILLIAMS, W. CARLETON, F.C.S. Firth College, Sheffield.
1865. ‡Williams, W. M. Stonebridge Park, Willesden.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., For. Sec. R.S., F.C.S., Corresponding Member of the French Academy. (GENERAL TREASURER.) University College, London, W.C.
1857. ‡WILLIAMSON, BENJAMIN, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1876. ‡Williamson, Stephen. 19 James-street, Liverpool.
WILLIAMSON, WILLIAM C., LL.D., F.R.S., Professor of Botany in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
1883. ‡WILLIS, T. W. 51 Stanley-street, Southport.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Clive House, Esher, Surrey.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1885. ‡Wilson, Alexander H. 2 Albyn-place, Aberdeen.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. 124 Bothwell-street, Glasgow.
1859. ‡Wilson, Alexander Stephen. North Kinmundy, Summerhill, by Aberdeen.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1874. ‡WILSON, Colonel Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. Mountjoy Barracks, Phœnix Park, Dublin.
1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.

Year of Election.

1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
1885. ‡*Wilson, Brigade-Surgeon G. A. East India United Service Club, St. James's-square, London, S.W.*
1875. ‡Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1883. *Wilson, Henry, M.A. Eastnor, Malvern Link, Worcestershire.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1886. ‡Wilson, J. E. B. Woodslee, Wimbledon, Surrey.
1857. ‡Wilson, James Moncrieff. Queen Insurance Company, Liverpool.
1865. ‡Wilson, Rev. James M., M.A., F.G.S. The College, Clifton, Bristol.
1884. ‡Wilson, James S. Grant. H.M. Geological Survey, Sheriff Court-buildings, Edinburgh.
1858. *Wilson, John. Seacroft Hall, near Leeds.
Wilson, John, F.R.S.E., F.G.S., Professor of Agriculture in the University of Edinburgh. The University, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1861. ‡Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.
1867. ‡Wilson, Rev. William. Free St. Paul's, Dundee.
1887. §Wilson, W., jun. Hillock, Terpersie, by Alford, Aberdeenshire.
1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1861. *Wiltshire, Rev. Thomas, M.A., F.G.S., F.L.S., F.R.A.S., Assistant Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, London, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. §Windle, Bertram C. A. 195 Church Hill-road, Handsworth, Birmingham.
1887. §Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.
1886. ‡Winter, George W. 55 Wheeley's-road, Edgbaston, Birmingham.
1887. §Winton, Colonel Sir F. de, K.C.M.G., F.R.G.S. 28 Wynnstay-gardens, Kensington, London, W.
1863. *Winwood, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1883. §Wolfenden, Samuel. Cowley Hill, St. Helen's, Lancashire.
1884. ‡Womack, Frederick, Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. 68 Abbey-road, London, N.W.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1883. §Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
*Wood, George B., M.D. 1117 Arch-street, Philadelphia, U.S.A.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. §Wood, H. Trueman, M.A. Society of Arts, John-street, Adelphi, London, W.C.
1883. *Wood, James, LL.D. Grove House, Scarisbrick-street, Southport.
1881. §Wood, John, B.A., F.R.A.S. Wharfedale College, Boston Spa, Yorkshire.
1883. *Wood, J. H. Woodbine Lodge, Scarisbrick New-road, Southport.
1886. ‡Wood, Rev. Joseph. Carpenter-road, Birmingham.
1883. §Wood, Mrs. Mary. Ellison-place, Newcastle-on-Tyne.
1883. ‡*Wood, P. F. Ardwick Lodge, Park-avenue, Southport.*
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.

Year of Election.

1871. ‡Wood, Provost T. Barleyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
Wood, William. Edge-lane, Liverpool.
1865. *Wood, William, M.D. 99 Harley-street, London, W.
1872. §Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *WOODALL, JOHN WOODALL, M.A., F.G.S. St. Nicholas House, Scarborough.
1870. ‡Woodburn, Thomas. Rock Ferry, Liverpool.
1884. ‡Woodbury, C. J. H. 31 Devonshire-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodcock T., B.A. The Old Hall School, Wellington, Shropshire.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, London, N.W.
1850. *Woodd, Charles H. L., F.G.S. Roslyn House, Hampstead, London, N.W.
1865. ‡Woodhill, J. C. Pakenham House, Charlotte-road, Edgbaston, Birmingham.
1871. ‡*Woodiwis James. 51 Back George-street, Manchester.*
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
1869. ‡*Woodman, William Robert, M.D. Ford House, Exeter.*
*WOODS, EDWARD, M.Inst.C.E. 6B Victoria-street, Westminster, London, S.W.
1883. ‡Woods, Dr. G. A., F.R.S.E., F.R.M.S. Carlton House, 57 Hoghton-street, Southport.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, London, E.C.
1887. *Woodward, Arthur Smith, F.G.S., F.L.S. 183B King's-road, Chelsea, London, S.W.
*WOODWARD, C. J., B.Sc. 97 Harborne-road, Birmingham.
1886. §Woodward, Harry Page, F.G.S. 129 Beaufort-street, London, S.W.
1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.
1870. ‡WOODWARD, HORACE B., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1881. ‡Wooler, W. A. Sadberge Hall, Darlington.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.
1883. *Woolley, George Stephen. 69 Market-street, Manchester.
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
WORCESTER, The Right Rev. HENRY PHILPOTT, D.D., Lord Bishop of. Hartlebury Castle, Kidderminster.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Stourbridge, Worcestershire.
Worthington, Archibald. Whitchurch, Salop.
Worthington, James. Sale Hall, Ashton-on-Mersey.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1879. §Wrentmore, Francis, 34 Holland Villas-road, Kensington, London, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.

Year of Election.

1883. *Wright, Rev. Benjamin, M.A. The Rectory, Darlaston.
1871. ‡WRIGHT, C. R. A., D.Sc., F.R.S., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.
1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.
1857. ‡WRIGHT, E. PERCEVAL, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany, and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1886. ‡Wright, Frederick William. 4 Full-street, Derby.
1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.
1876. ‡Wright, James. 114 John-street, Glasgow.
1874. ‡Wright, Joseph. Cliftonville, Belfast.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. ‡Wright, Professor R. Ramsay, M.A., B.Sc. University College, Toronto, Canada.
WRIGHT, T. G., M.D. Milnes House, Wakefield.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡Wrightson, Thomas, M.Inst.C.E., F.G.S. Norton Hall, Stockton-on-Tees.
1887. §Wrigley, Rev. Dr., M.A., M.D., F.R.A.S. 15 Gauden-road, London, S.W.
Wyld, James, F.R.G.S. Charing Cross, London, W.C.
1867. ‡Wylie, Andrew. Prinlaws, Fifeshire.
1883. ‡Wyllie, Andrew. 10 Park-road, Southport.
1885. ‡Wyness, James D., M.D. 53 School-hill, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.

1875. ‡Yabbicom, Thomas Henry. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.
1883. ‡Yates, James. Public Library, Leeds.
1867. ‡Yeaman, James. Dundee.
1887. § Yeats, Dr. Chepstow.
1884. ‡Yee, Fung, Secretary to the Chinese Legation. 49 Portland-place, London, W.
1879. ‡Yeomans, John. Upperthorpe, Sheffield.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1879. *YORK, His Grace the Archbishop of, D.D., F.R.S. The Palace, Bishopthorpe, Yorkshire.
1884. §York, Frederick. 87 Lancaster-road, Notting Hill, London, W.
1886. *YOUNG, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Frederick. 5 Queensberry-place, London, S.W.
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